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NEW CONSTRUCTIONS IN GRAPHICAL STATICS.

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I.

It is the object of the series of articles, of which this is the first, to fully discuss the stability of all forms of the arch, flexible or rigid, by means of the equilibrium polygon—the now well recognized instrument for graphical investigation. One or two other constructions of interest may also be added in the sequel. The discussion will pre-suppose an elementary knowledge of the properties of the equilibrium polygon, and its accompanying force polygon, for parallel forces.

As ordinarily used in the discussion of the simple or continuous girder, the equilibrium polygon has an entirely artificial relation to the problem in hand, and the particular horizontal stress assumed is a matter of no consequence; but not so with respect to the arch. As will be seen, there is a special equilibrium polygon appertaining to a given arch and load, and in this particular polygon the horizontal stress is the actual horizontal thrust of the arch. When this thrust has been found in any given case, it permits an immmediate determination of all other questions respecting the stresses. This thrust has to be determined differently in arches of different kinds, the method being dependent upon the number, kind, and position of the joints in the arch.

The methods we shall use depend upon our ability to separate the stresses induced by the loading into two parts; one part being sustained in virtue of the reaction of the arch in the same manner as an inverted suspension cable (*i.e.*, as an equilibrated linear arch), and the remainder in virtue of its reaction as a girder. These two ways in which the loading is sustained are to be considered somewhat apart from each other. To this end it appears necessary to restate and discuss, in certain aspects, the well-known equations applicable to elastic girders acted on by vertical pressures due to the load and the resistances of the supports.

Let P represent any one of the various pressures, P_1, P_2, P_n, applied to the girder.

Consider an ideal cross section of the girder at any point O.

Let x=the horizontal distance from O to the force P.

Let R=the radius of curvature of the girder at O.

At the cross section O, the equations just mentioned become

Shearing stress, $S=\Sigma\,(P)$

Moment of flexure, $M=\Sigma\,(Px)$

Curvature, $$P'=\frac{1}{R}=\frac{M}{EI}$$

Total bending, $$B=\Sigma(P')=\Sigma\left(\frac{M}{EI}\right)$$

Deflection, $$D=\Sigma\,(P'x)=\Sigma\left(\frac{Mx}{EI}\right)$$

in which E is the modulus of elasticity of the material, and I is the moment of inertia of the girder, and as is well known, the summation is to be extended from the point O to a free end of the girder, or, if not to a free end, the summation expresses the effect only of the quantities included in the summation.

Let a number of points be taken at equal distances along the girder, and let the values of P, S, M, B, D be computed for these points by taking O at these points successively, and also erect ordinates at these points whose lengths are proportional to the quantities computed. First, suppose I is the same at each of the points chosen, then the values of these ordinates may be expressed as follows, if a, b, c, etc., are any real constants whatever:

$$yp = a\,.\,P \quad . \quad . \quad . \quad (1)$$
$$ys = b\,.\,\Sigma(P) \quad . \quad . \quad (2)$$
$$ym = c\,.\,\Sigma(Px) = c\,.\,M. \quad . \quad (3)$$
$$yb = d\,.\,\Sigma(M) \quad . \quad . \quad (4)$$
$$yd = \varepsilon\,.\,\Sigma(Mx) \quad . \quad . \quad (5)$$

If I is not the same at the different cross sections, then the last three equations must be replaced by the following:

$$ym' = f\,.\,P' \quad . \quad . \quad (3')$$
$$yb' = g\,.\,\Sigma(P') \quad . \quad . \quad (4')$$
$$yd' = h\,.\,\Sigma(P'x) \quad . \quad . \quad (5')$$

The ordinates ym and ym' are not equal, but can be obtained one from the other when we know the ratio of the moments of inertia at the different cross sections.

Equation (1) expresses the loading, and yp may be considered to be the depth of some uniform material as earth, shot or masonry constituting the load. Lines joining the extremities of these ordinates will form a polygon, or approximately a curve which is the upper surface of such a load. When the load is uniform the surface is a horizontal line.

For the purposes of our investigation, a distributed load whose upper surface is the polygon or curve, above described, is considered to have the same effect as a series of concentrated loads proportional to the ordinates yp acting at the assumed points of division. If the points of division be assumed sufficiently near to each other, the assumption is sufficiently accurate.

If a polygon be drawn in a similar manner by joining the extremities of the ordinates ym computed from equation (3), it is known that this polygon is an equilibrium polygon for the applied weights P, and it can also be constructed directly without computation by the help of a force polygon having some assumed horizontal stress.

Now, it is seen by inspection that equations (3) and (5), or (3′) and (5′), have the same relationship to each other that equations (1) and (3) have. The relationship may be stated thus:—If the ordinates ym (or ym') be regarded as the depth of some species of loading, so that the polygonal part of the equilibrium polygon is the surface of such load, then a second equilibrium polygon constructed for this loading will have for its ordinates yd. But these last are proportional to the actual deflections of the girder.

Hence a second equilibrium polygon, so constructed, might be called the deflection polygon, as it shows on an exaggerated scale the shape of the neutral axis of the deflected girder.

The first equilibrium polygon having the ordinates ym may be called the moment polygon.

It may be useful to consider the physical significance of equations (3), (4), (5), or (3′), (4′), (5′).

According to the accepted theory of perfectly elastic material, the sharpness of the curvature of a uniform girder is directly proportional to the moment of the applied forces, and for different girders or different portions of the same girder, it is inversely proportional to the resistance which the girder can afford. Now this resistance varies directly as I varies, hence curvature varies as $M \div I$, which is equation (3) or (3′).

Now curvature, or bending at a point, is expressed by the acute angle between two tangents to the curve at the distance of a unit from each other; and the total

bending, *i.e.* the angle between the tangent at O, and that at some distant point A is the sum of all such angles between O and the point A. Hence the total bending is proportional to $\Sigma(M \div I)$, the summation being extended from O to the point A, which is equation (4) or (4′).

Again, if bending occurs at a point distant from O as A, and the tangent at A be considered as fixed, then O is deflected from this tangent, and the amount of such deflection depends both upon the amount of the bending at A, and upon its distance from O. Hence the deflection from the tangent at A is proportional to $\Sigma\,(Mx \div I)$ which is equation (5) or (5′).

It will be useful to state explicitly several propositions, some of which are implied in the foregoing equations. The importance and applicability of some of them has not, perhaps, been sufficiently recognized in this connection.

Prop. I. Any girder (straight or otherwise) to which vertical forces alone are applied (*i. e.*, there is no horizontal thrust) sustains at any cross-section the stress due to the load, solely by developing one internal resistance equal and opposed to the shearing, and another equal and opposed to the moment of the applied forces.

Prop. II. But any flexible cable or arch with hinge joints can offer no resistance at these joints to the moment of the applied forces, and their moment is sustained by the horizontal thrust developed at the supports and by the tension or compression directly along the cable or arch.

It is well known that the equilibrium polygon receives its name from its being the shape which such a flexible cable, or equilibrated arch, assumes under the action of the forces. In this case we may say for brevity, that the forces are sustained by the cable or arch in virtue of its being an equilibrium polygon.

Prop. III. If an arch not entirely flexible is supported by abutments against which it can exert a thrust having a horizontal component, then the moment due to the forces applied to the arch will be sustained at those points which are not flexible, partly in virtue of its being approximately an equilibrium polygon, and partly in virtue of its resistance as a girder.

It is evident from the nature of the equilibrium polygon that it is possible with any given system of loading to make an arch of such form (viz., that of an equilibrium polygon) as to require no bracing whatever, since in that case there will be no tendency to bend at any point. Also it is evident that any deviation of part of the arch from this equilibrium polygon would need to be braced. As, for example, in case two distant points be joined by a straight girder, it must be braced to take the place of part of the arch. Furthermore, the greater the deviation the greater the bending moment to be sustained in this manner. Hence appears the general truth stated in the proposition.

It will be noticed that the moment called into action, at any point of a straight girder, depends not only on the applied forces which furnish the polygonal part of the equilibrium polygon, but also on the resistance which the girder is capable of sustaining at joints or supports, or the like. For example, if the girder rests freely on its end-supports, the moment of resistance vanishes at the ends, and the "closing line" of the polygon joins the extremities of the polygonal part. If however the ends are fixed horizontally and there are two free (hinge) joints at other points of the girder, the polygonal part will be as before, but the closing line would be drawn so that the moments at those two points vanish. Similarly in every case (though the conditions may be more complicated than in the examples used for illustration) the position of the closing line is fixed by the joints or manner of support of the girders, for these furnish the conditions which the moments (*i. e.*, the ordinates of the equilibrium polygon) must fulfill. For example, in a straight uniform girder without joints and fixed horizontally at the ends, the conditions are evidently these; the total bending vanishes when taken from end to end, and the deflection of one end below the tangent at the other end also vanishes.

Prop. IV. If in any arch that equilibrium polygon (due to the weights) be constructed which has the same horizontal thrust as the arch actually exerts; and if its closing line be drawn from consideration of the conditions imposed by the supports, etc.; and if furthermore the curve of the arch itself be regarded as another equilibrium polygon due to some system of loading not given, and its closing line be also found from the same considerations respecting supports, etc., then, when these two polygons are placed so that these closing lines coincide and their areas partially cover each other, the ordinates intercepted between these two polygons are proportional to the real bending moments acting in the arch.

Suppose that an equilibrium polygon due to the weights be drawn having the same horizontal thrust as the arch. We are in fact unable to do this at the outset as the horizontal thrust is unknown. We only suppose it drawn for the purpose of discussing its properties. Let also the closing line be drawn, which may be done, as will be seen hereafter. Call the area between the closing line and the polygon, A. Draw the closing line of the curve of the arch itself (regarded as an equilibrium polygon) according to the same law, and call the area between this closing line and its curve A''. Further let A' be the area of a polygon whose ordinates represent the actual moments bending the arch, and drawn on the same scale as A and A''. Since the supports etc., must influence the position of the closing line of this polygon in the same manner as that of A, we have by Prop. III not only

$$A = A' + A''$$

which also applies to the entire areas, but also

$$y = y' + y''$$

as the relation between the ordinates of these polygons at any of the points of division before mentioned, from which the truth of the proposition appears.

This demonstration in its general form may seem obscure since the conditions imposed by the supports, etc., are quite various, and so cannot be considered in a general demonstration. The obscurity, however, will disappear after the treatment of some particular cases, where we shall take pains to render the truth of the proposition evident. We may, however, make a statement which will possibly put the matter in a clearer light by saying that A'' is a figure easily found, and we, therefore, employ it to assist in the determination of A' which is unknown, and of A which is partially unknown. And we arrive at the peculiar property of A'', that its closing line is found in the same manner as that of A, by noticing that the positions of the closing lines of A and A' are both determined in the same manner by the supports, etc.; for the same law would hold when the rise of the arch is nothing as when it has any other value. But A'' is the difference of A and A'. Hence what is true of A and A' separately is true of their difference A'', the law spoken of being a mere matter of summation.

From this proposition it is also seen that the curve of the arch itself may be regarded as the curved closing line of the polygon whose ordinates are the actual bending moments, and the polygon itself is the polygonal part of the equilibrium polygon due to the weights.

It is believed that Prop. IV contains an important addition to our previous knowledge as to the bending moments in an arch, and that it supplies the basis for the heretofore missing method of obtaining graphically the true equilibrium polygon for the various kinds of arches.

Prop. V. If bending moments M act on a uniform inclined girder at horizontal distances x from O, the amount of the vertical deflection yd will be the same as that of a horizontal girder of the same cross section, and having the same horizontal span, upon which the same moments M act at the same horizontal distances x from O. Also, if bending moments M act as before, the amount of the horizontal deflection, say x_d, will be the same as that of a vertical girder of the same cross section, and having the same height, upon which the same moments M act at the same heights.

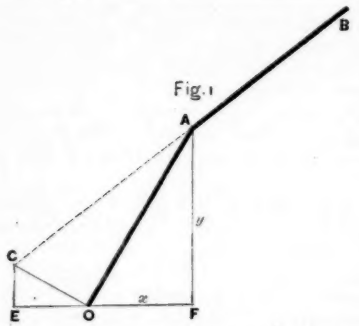


Fig. 1

Let the moment M act at A, producing according to equation (5) the deflection

$$OC = e \,.\, M \,.\, AO$$

whose horizontal and vertical components are

$$y_d = CE \quad \text{and} \quad x_d = OE$$

For the small deflections occurring in a girder or arch, $AOC = 90°$

$$\therefore \; AO : OF :: OC : CE$$

$$\therefore \; CE = \frac{OC}{AO} OF = e.M.OF$$

$$\therefore \; yd = e \,.\, Mx$$

$$\text{Also, } AO : AF :: OC : OE$$

$$\therefore \; OE = \frac{OC}{AO} .AF = e.M.AF$$

$$\therefore \; x_d = e.My$$

The same may be proved of any other moments at other points; hence a similar result is true of their sum; which proves the proposition.

It may be thought that the demonstration is deficient in rigor by reason of the assumption that $AOC = 90°$.

Such, however, is not the fact as appears from the analytic investigation of this question by Wm. Bell in his attempted graphical discussion of the arch in Vol. VIII of this Magazine, in which the only approximation employed is that admitted by all authors in assuming that the curvature is exactly proportional to the bending moment.

We might in this proposition substitute $f.M \div I$ for $e \,.\, M$, and prove a similar but more general proposition respecting deflections, which the reader can easily enunciate for himself.

Before entering upon the particular discussions and constructions we have in view, a word or two on the general question as to the manner in which the problem of the arch presents itself, will perhaps render apparent the relations between this and certain previous investigations. The problem proposed by Rankine, Yvon-Villarceaux, and other analytic investigators of the arch, has been this :—Given the vertical loading of an arch, what must be its form, and what must be the resistances of the spandrils and abutments, when the weights produce no bending moments whatever? By the solution of this question they obtain the equation and properties of the particular equilibrium polygon which would sustain the given weights. Our graphical process completely solves this question by at once constructing this equilibrium polygon. It may be remarked in this connection, that the analytic process is of too complicated a nature to be effected in any, except a few, of the more simple cases, while the graphical process treats all cases with equal ease. But the kind of solution just noticed, is a very incomplete solution of the problem presented in actual practice; for, any moving load disturbs the distribution of load for which the arch is the equilibrium polygon, and introduces bending moments. The arch must then be proportioned to resist these moments.

For similar reasons it is not necessary to stiffen a suspension bridge. Since this is the case, it is of no particular consequence that the form adopted for the arch in any given case, should be such as to entirely avoid bending moments when not under the action of the moving load. So far as is known to us, it is the universal practice of engineers to assume the form and dimensions, as well as the loading of any arch projected, and next to determine whether the assumed dimensions are consistent with the needful strength and stability. If the assumption is unsuited to the case in hand, the fact will appear by the introduction of excessive bending moments at certain points. The considerations set forth furnish a guide to a new assumption which shall be more suitable, it being necessary to make the form of the arch conform more closely to that of the equilibrium polygon for the given loading.

The question may be regarded as one

of economy of material, and ease of construction, analogous to that of the truss bridge. In this latter case, constructors have long since abandoned any idea of making bridges in which the inclination of the ties and posts should be such as to require theoretically the minimum amount of material. Indeed, the amount of material in the case of a theoretic minimum, differs by such an inconsiderable quantity from that in cases in which the ties and posts have a very different inclination, that the attainment of the minimum is of no practical consequence.

Similar considerations applied to the arch, lead us to the conclusion that the form adopted can in every case be formed of segments of one or more circles, and that for the purpose of construction every requirement will then be met as fully as by the more complicated transcendental curves found by the writers previously mentioned. If considerations of an artistic nature render it desirable to adopt segments of parabolas, ellipses or other ovals, it will be a matter of no more consequence than is the particular style of truss adopted by rival bridge builders.

We can also readily treat the problem in an inverse manner, viz :—find the system of loading, of which the assumed curve of the arch is the equilibrium polygon. From this it will be known how to load a given arch so that there shall be no bending moments in it. This, as may be seen, is often a very useful item of information ; for, by leaving open spaces in the masonry of the spandrils, or by properly loading the crown to a small extent, we may frequently render a desirable form entirely stable and practicable.

FIRE-BRICKS.*

By Mr. J. DUNNACHIE.

From "Iron."

The fire-brick question may be viewed from various sides. The owner of furnaces who uses the bricks, the man of science who has to do with their chemistry and other technicalities, and the brickmakers who manufacture them, should all have something to say on the subject. In the present paper, we will view it from the brickmaker's standpoint, and will strictly confine ourselves to that branch of the fire-clay trade indicated by the title.

The iron and steel manufacturer, who may be taken as the representative of furnace owners, has in various ways recently shown a deep interest in this subject. In the iron trade journals of this and other countries, it bulks up as one of the pressing questions, and at the last three meetings of the Iron and Steel Institute, it has been under discussion, in connection with a paper read by Mr. Snelus, of the West Cumberland Iron and Steel Company, which will be found published in the reports of the Institute for 1875 and 1876. These discussions are valuable, being the latest utterances of some of our first scientific and practical men.

The metal smelter observes that his furnaces, unlike his other buildings, are continually melting and crumbling away. He is steadily increasing the magnitude of his operations, and the intensity of his heats, and finds his progress arrested by the weakness of his furnace materials. The tear and wear has increased, until it has become a serious item in the cost of production, and for this he naturally seeks a remedy. This is pre-eminently a chemical question, not for analysis merely, but that every peculiarity of form, proportion, relationship, and general conditions may be carefully and accurately observed, and data established, which will give us something to aim at and something to guide us in our everyday practice as manufacturers. Much has been done already, and there are indications of an increasing chemical interest in the subject, which, with the co-

* A paper read at the British Association, Glasgow.

operation of the consumers and manufacturers of fire-bricks, may ultimately lead to results that will meet all the wants of practical metallurgy.

Silica, alumina, bauxite, carbon, magnesia, lime, are all highly refractory, the two first-named, silica and alumina, being the essential constituents of our fire-clays. Lime and magnesia, though practically indestructible by heat, fuse easily when combined with silica, and are consequently classed with oxide of iron, potash, soda, &c., amongst the impurities of fire-clay. Experiments are at present in progress with several of the ingredients named, and important results are expected in more directions than one.

The great variety of purposes for which fire-bricks are used, and the various, and even opposite qualities required in them, make it impossible that one brick can answer for all descriptions of furnaces. They require to stand strong heat, change of temperature, in some cases heavy pressure, and hard knocks, and also fluxing and chemical action of various kinds. For all these purposes we require not one, but a variety of bricks, and this variety we will probably find sooner or later in the different refractory substances at our disposal.

The age of a fire-brick depends upon the purpose for which it is used. In some situations it may be counted by minutes, in others by years; and some bricks will last for years in positions where others also bearing the name of fire-bricks would be destroyed in as many weeks.

The name fire-clay covers a multitude of qualities, and fire-bricks differ to such an extent chemically, and as manufactured articles, that if their names were to indicate their qualities, rather than the general purpose to which they are put, a great many new names would require to be invented or imported. Although no one brick answers for all purposes, a great deal can be done in the process of manufacture to fit it for the particular use to which it is to be put; one requires to be solid and close-bodied, another porous and open; in certain special cases soft burning is preferred, while in others they cannot be too hard. As a general rule, fire-bricks should be hard burned. The shrink from the green state to the burned condition is generally about one-twelfth of the bulk, and if this is not entirely reduced in the kiln, some of it will require to be burned out of them after they are built in the furnace, and this must injure the stability of the furnace.

Mixing clays of different kinds has been recommended, with the view of combining the good qualities of each, and more especially to increase or diminish the relative proportion of silica. This may do good in some cases, but as all fire-clays have their bad qualities also, mixing will, in many cases, increase the force of these, and so do more harm than good. Riley says, touching this point, "In considering the qualities of a fire-brick, chemically, the bases that have a fluxing action should be considered as a whole. A brick might contain more oxide of iron than it should do, yet on account of its being far from other bases, it might nevertheless be a good brick." We thus see that the number of the objectionable ingredients, as well as their aggregate quantity, has something to do with the result; besides a natural chemical combination, an artificial mixture might give the same analysis, and yet be very different as a fire-brick making material.

Those containing the largest percentage of silica, if otherwise pure (such as the Dinas of South Wales), stand best in the highest heats, but are liable to split up by sudden heating or cooling. A brick high in silica, yet containing a fair proportion of alumina, and comparatively free from alkalies and other impurities, is the one which combines in the highest degree infusibility and freedom from splitting; and is, consequently, found to be best suited for all such purposes as puddling, rolling, and forging, and the Siemens regenerator, where the great desideratum is precisely the combination of these qualities. A sample of clay from the Glenboig Star Mine was recently analysed by Riley, and, after being calcined, gave the following results: Silica 65.41 per cent; titanic acid, 1.33; alumina, 30.55; peroxide of iron, 1.7; lime, 0.69; magnesia, 0.64; potash, with a little soda, 0.55. Total 100.87 per cent.

To get a really good furnace, we must first procure the best materials for

its construction; but after that, much depends upon how it is built. If we were as careful about the lines of our furnaces as we are about the lines of our ships, and as particular about the quality of the materials and workmanship employed, as the importance of the subject demands, we might, in many cases, double their duration, without waiting for the possible discoveries of the future. However anxious we may be for improvement, in the meantime we must make the most of the materials we possess, and of our present knowledge of the modes of manipulation.

The making of a fire-brick is like the making of a pin—the article looks a simple one, yet the process is complex and somewhat elaborate. Some of our most ingenious machines have the intelligence put into them at the beginning, and are afterwards almost self-acting; and while this can be done to some extent, in setting down a new fire-brick work, still in no process is close and careful attention more essential, if the best results are to be obtained. As in scientific investigation, the smallest gleam of truth has its value and its place, so in the workshop every little bit of ascertained fact has its value also, and if it gets its place, it will certainly bring its reward in the general result.

The fire-brick trade of Glasgow cannot lay claim to the antiquity which belongs to Stourbridge or Newcastle. It only dates back some forty or fifty years, when it was first started at Garnkirk, and is therefore comparatively young. But it is healthy, and even already well grown. For years past it has entered into friendly rivalry with the older seats of manufacture, and found markets in all parts of the world, and notably in the northern and midland counties of England, to which districts one or two of the best brands are sent in large quantities.

The quantity of fire-bricks annually made in the Glasgow district, which is almost exclusively comprised in the counties of Lanark, Renfrew, and Ayr, will amount in ordinary times to eighty millions. In addition to this there is manufactured an enormous quantity of sanitary pipes, gas retorts, and other articles in fire-clay, both useful and ornamental. Considerable quantities of fire-bricks are also made in the neighborhood of Edinburgh and in the counties of Stirling and Fife; but these I have not the means of estimating.

The fire-clays wrought in the neighborhood of Glasgow are situated geologically in the upper coal series and limestone series, taking the Roman cement as the dividing line, or, according to the Ordnance geological map, in the millstone grit. They are found at all depths, from the surface, opencast workings, to pits of forty to fifty fathoms. They are sometimes taken from lower depths, where coal is being wrought; but we do not find our best qualities in such positions. The workable seams vary in thickness from about three feet to thirty or forty feet. The process of fire-brick making is pretty much alike all over the West of Scotland, and, indeed, everywhere else, when fire-clay is the material employed; but, as it is necessary to be clear and connected, we will follow the process as applied at the Glenboig Star Works. The clay is there found 113 feet deep, and varies in thickness from six to nine feet. In descending the shaft, we pass through from twelve to twenty feet of floating whinstone, which covers a considerable part of the Glenboig district; under this are numerous beds of fire-clay and silicious rocks, some of them almost pure silica. The system of mining is what is called stoop-and-room, or pillar-and-stall. The workings are twelve feet wide, and the stoops left in are thirty feet square, excepting at the pit bottom, where they are much larger. The stoops may be cut through, and, when the proper time comes removed altogether. The clay, in its natural state, is very hard, and requires to be blown down with gunpowder. The average daily output of each man, unaided, is from four to five tons, according to the thickness or hardness of the clay. The clay is sent out in pieces about the size of good round coal. It is raised to a high pit-head platform, from whence it is run either to the crushing-mills direct, or to the bing, where it is exposed to the action of the weather.

When weathering is adopted, the extra labor of lifting and laying is involved, but the ease with which the milling is afterwards effected fully compensates. When the clay is mixed with "bullets"

or nodules of iron, or any other visible impurities, weathering permits of these being picked out with ease. It disintegrates and softens the clay, so that a much solider body and smoother surface can be given to such articles as require these qualities.

In bricks for general furnace purposes we do not want a close texture. The brick must have sufficient flour in it to give it toughness and strength, that it may bear the rough shunting of our railways and the careless treatment which fire-bricks too often receive in shipping and trans-shipping. But that accomplished, our aim is to make them as rough and open in the grain as possible, that they may be the better able to resist high and variable temperatures.

The crushing and milling are effected by means of revolving pans, in which heavy iron-edge rollers run. The crushing pan is seven feet in diameter, and perforated in the bottom; the crushing-rollers weigh upwards of three tons each. The wet pans are six feet in diameter, and the rollers weigh 35 cwt. each. They receive their motion from a large shaft running overhead, and connected with the fly-wheel of the engine.

The clay is first broken with hammers and shovelled into the crushing mill. The bottom of the pan has rows of perforations through which the clay is crushed. Scrapers, attached to the pan beneath, throw it into an iron box, from whence it is lifted about twenty feet by means of an endless chain, fitted with elevator buckets, which deliver it into a cylindrical riddle eight feet long and two and a half feet in diameter; this is so placed that the riddled clay drops to a second set of elevators, while the pieces too large to pass through drop back into the crushing mill. This second set of elevators has two duties to perform. It either sends the fine ground fire-clay which is used as mortar in furnace building to an endless belt which carries it to the wagons on the railway outside, or the rougher brick clay to the tempering pans by means of a box sixty feet long, placed overhead. In this box there is a traveling chain fitted with clats by means of which the clay is dragged along. In the bottom of the box are four holes, to which four conductors are attached, one to each mill. These, from their position, are always kept full, and when the millman requires clay, he has only to draw a sluice at the lower end of the conductor, and the clay drops into the pan. He then turns on the water, and the mill is charged in a second or two.

For mortar clay a riddle with 196 meshes to the square inch is used, and for brick-clay one of twenty meshes. In preparing clay for glasshouse blocks, gas retorts, Bessemer tuyeres, and all large articles, a proportion of previously burned bricks or clay is added, to prevent cracking in the drying. Pug mills are generally employed for tempering where the clay is of a soft aluminous nature, but they are not suitable for hard, gritty, silicious clays. When ready for moulding, the clay is discharged into small tipping bogies, which are raised by means of a steam hoist to the upper floor of the drying stove. It is there run along a little railway, from whence it is dropped down through suitable openings to the moulders' benches. By this method one man delivers the clay to nine or ten moulders. It has also the advantage of taking the traffic off the drying floor. Once in the moulder's hands, it is rapidly turned into bricks. A good workman with his carrier will make 2500 bricks a day.

Solid brass moulds are used for regular sizes, but for odd kinds and the larger sizes wooden moulds are employed. Iron, zinc, and glass have been tried; but hard brass has many advantages. The moulds are made a twelfth larger than the size of the burned brick, to allow for shrinkage. The face-board on which the brick is made is covered with thick plaiding, and the trade mark is fixed upon it, so that making and stamping are performed in one operation. Machinery is successfully employed in moulding common building bricks from stiff plastic clay, and also in the manufacture of dry or semi-dry compressed bricks from various materials; but no machine has yet been made capable of taking well milled fire-clay as it leaves the pans, turning it rapidly into bricks, and delivering them square and sharp-edged on to pallet-boards.

When the brick is moulded by hand, the moulder discharges it on to a pallet-board, the carrier then places another

board on the top of it, and between the two the soft brick is carried with safety, and deposited on edge on the stove floor, where it remains till hard and dry, when it is taken to the kiln.

The defects most common in fire-bricks, with the exception of soft burning, are produced in the stove, and it is here alone that soundness and finish can be given to them. If the stove floor is uneven, the shape of the brick is spoiled; and if too much heat is applied, the bricks are warped and cracked. Some clays are very liable to crack when too quickly dried; and where stoves are badly constructed, this occasions loss, and injures the quality of the brick to a serious extent. Where some are cracked through, others are partially cracked, and so on through all the stages of cracking, up to the sound ringing brick. Bricks of this description give also increased breakage in the kiln, and indeed in every stage of their existence.

To meet all this, a recently patented construction of stove is employed. The stoves are 120 feet in length, by 36 feet wide, and are fired from one end. The drying floors are entirely formed with cast-iron plates, each four feet by two feet, by $\frac{5}{8}$ of an inch. These are smooth and easily heated. Underneath the iron floor there is another, formed of fire-clay slabs, four inches and three inches thick, which runs from the furnace end to the middle of the stove, a distance of sixty feet.

The fires and hot flues are underneath the fire-clay slabs, and between the fire-clay slabs and the iron plates forming the upper floor there is an air-space of eight inches deep; this communicates with the outer air at the gable over the fires. Each flue has its own air-space. By this means the stove may be fired up so as to heat effectually the back end, while too much heat on the furnace end is prevented by the current of cold air passing between the two floors, till it joins the lower flue at the middle of the stove, carrying with it the superfluous heat of the furnace end, and utilizing it where it is required. Two such stoves, of the dimensions named, are turning out from 20,000 to 24,000 bricks a day. Every brick is ready for the kiln the day after it is moulded. By this system of drying, the cost is lessened, while the production for a given space is nearly doubled.

Various other methods have been tried, such as exhaust steam in pipes or flues, and hot air, in a variety of ways. In such cases shelving is generally employed, and this entails extra labor and expense. The method just described is, in every respect, to be preferred, particularly where large production and perfect regularity are required.

When dry, the bricks are wheeled to the kiln, where they are built up in chequered walls, each brick being nearly an inch apart. A kiln contains from 16,000 to 20,000 bricks; when filled, the doors are built up, and the fires kindled. The firing is done very gently at first, the furnace being open, and also the holes in the crown of the kiln; this is continued for two days, till the damp is completely steamed out of them, after which the crown of the kiln is carefully closed, the draught is connected with the chimney, and the kiln is put on full fire.

This takes other two or three days, during which time it is steadily brought up to a bright white heat, at which it is maintained till the necessary sink in the bricks has taken place, after which the firing ceases, and the kiln is gradually cooled down.

The kilns are built in pairs, back to back, and are fired from the one side across; the floor is not chequered, excepting over the flue which runs along the back, and through which the draught passes on its way to the chimney, either direct or through another kiln. The fires are on the hopper principle, something after the style of the Siemens' producer. They are supplied with hot air heated under the floor of the kiln, and in addition there is a good sized flue run from end to end of the kiln over the fires, through which cold air is supplied to each fire. Without this, the front of the kiln would become too hot; with it this is prevented, and the air thus introduced, after passing through the kiln, which acts as a kind of regenerator, combines at the back with the unconsumed gases, giving great evenness of burning and also great economy.

The Newcastle kiln is the one generally used, and here and there the old Scotch or Leeds kiln is to be met with,

but these are too expensive in times of dear coal.

In conclusion, let us ask, How are we to meet the want, so frequently and urgently expressed, for "cheaper and better fire-bricks?" To some, cheapening suggests a reduction of price, but this would be no answer to the present demand. If the price were reduced until it disappeared altogether, and the quality of the brick remained unsatisfactory, the want would still be felt all the same.

What is required is a superior quality, so that the price, whatever it may be, will be found to be cheap when viewed in relation to the service rendered. Something may yet be done to economise fuel, and machinery may yet reduce the item of wages, and at the same time improve the condition of the workman; but if the requirements of modern metallurgy in this matter are to be fully met, it must be principally by the improvements of the quality of our furnace materials.

RETAINING WALLS.

By E. SHERMAN GOULD, C. E.

Written for Van Nostrand's Engineering Magazine.

The following is an attempt to place the calculation of ordinary retaining walls upon its simplest footing. As regards the higher and more exact investigations of the subject. I am well aware that there remains but little to be said, for in the pages of this magazine, and elsewhere, they have been developed with a completeness nearly, or quite exhaustive.

My aim is therefore, to follow the subject only so far as the most elementary processes of applied Mechanics will permit, but it will be found, I think, that these processes are quite adequate to the solution of even somewhat complex problems.

In designing a retaining wall, it is always easy to prepare a draft which will ensure stability; precedent and certain well-known formulæ, are sufficient guides for this, but what we want to get at by calculation is, the best *form* of cross-section. For instance: Given a certain volume of wall destined to sustain a certain mass of earth or head of water, should the wall be straight or battering? and if battering, should the batter occur on the exterior or interior faces, or both? In other words, what form of cross-section will give a maximum and *uniform* strength, so that the weight of the wall may act with the longest possible lever-arm, and that the wall may not be redundantly strong in some parts, and only just (or not) strong enough in others?

Now, though the minute and ultimate determinations of these questions may demand the aid of the higher mathematics, their approximate and, in ordinary cases, sufficient solution may be easily reached by far simpler processes.

Setting aside, as foreign to our present purpose, the exceedingly important consideration of foundations, there are three ways in which a retaining wall may fail. First it may fail by overturning; secondly, by sliding, and third by a combination of the above.

Of these, the last is probably the most frequent. The second rarely, or never occurs except in the case of a wall resting on a slippery bottom, while the first is a case of not infrequent occurrence, and is in fact what would commonly happen to a too thin wall, well laid up with good materials.

It is obvious that we can reach by calculation, only two, namely, the first and second, of these cases. But this is quite sufficient, for if we prove our structure to be safe against overturning *or* slipping from a single force, it must be safe against overturning *and* slipping from the same.

It is usual, in designing a retaining wall, to calculate only its tendency to turn, as a body, around its foot, or slide, as a body, upon its base. This is not

sufficient to ascertain if the before-mentioned requirements are fulfilled. In a straight wall, of equal thickness throughout, indeed, this calculation will be *safe*, for, as we shall presently see, the lowest course is the weakest part of an earth-sustaining wall, but the upper courses will have redundant width; and in the case of a battering wall, especially if the battering faces be curved, the upper courses may not be sufficiently deep for safety, though the lowest course may.

It must be born in mind, that all these calculations are subject to certain limitations of accuracy, arising from the nature of the construction. Thus, a certain part of a given wall may be shown by calculation to be that suffering the maximum stress, and yet, from extra good workmanship and material at that particular point it may be the last place at which the wall would fail, and *vice versa*. These circumstances cannot of course be taken account of in the design; the wall must be designed on the assumption of equally good workmanship throughout, and it falls to the duty of those intrusted with the execution of the work to see that this assumption is vindicated.

If we dig a trench, or other excavation with vertical sides, we see that the earth, sooner or later, and to a greater or less extent according to the nature of the soil, crumbles and falls until it assumes its *natural slope*. All that is not in equilibrium has then come away, and the sides have assumed their permanent state of rest. Now the object of the retaining wall is to hold up the unequilibriated mass of earth which would otherwise be detached, and fall. In order to ascertain what the extent of this mass might be, let us consider what would be the result of suddenly and bodily removing the straight retaining wall A, Fig. 1: A portion of the earth would fall,

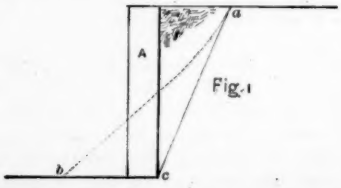


Fig. 1

and sooner or later assume some such slope as that shown by the dotted curve *a b*. It is evident, therefore, that the wall has to sustain the pressure of some such prism of earth as might lie between its inner face and the imaginary slope *a c*. It is shown mathematically, but by reasoning from more subtle considerations than those involved in the above rough illustration, that the true prism of pressure lies between the retaining wall and a line drawn from its foot, called the line of rupture, inclined to the vertical at an angle equal to one half of the angle of natural slope. (*Note*—The fact that these are the true boundaries of the prism of pressure, receives corroboration by a reference to hydrostatic pressure. In this case the angle of natural slope would be 90°. Half of this, or 45°, would then give the line of rupture. Calculating the prism of pressure from this datum, we get the same as that reached by other, and undeniably correct methods of calculation).

This prism acts against the wall like a wedge driven vertically downward by its own weight, and moving, or tending to move along the sloping surface of the line of rupture. Thus, in the prism *a b c* (Fig. 2) tending to slide downward

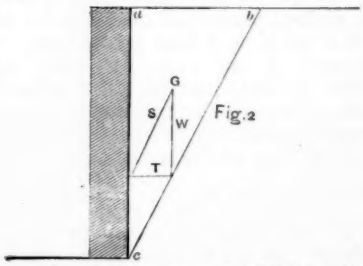
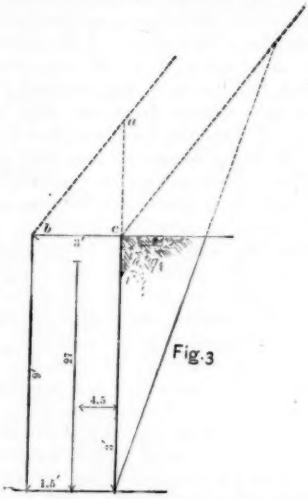


Fig. 2

along *c b*, we have the weight W = radius, acting from the center of gravity G of the prism, and striking the inner face of the wall along the secant S of the angle of rupture, at one-third of the height of the wall from its base (because G is at one-third of the altitude of the triangle *a b c*). The weight, thus acting, tends to thrust the wall out with a force represented by the tangent T of the angle of rupture. *The pressure tending to cause sliding along the base of the wall is therefore equal to the weight of the prism of pressure a b c multiplied by the tangent of the angle of rupture a c b; and the moment tending to produce overturning around the foot of the wall, is equal to*

the above multiplied by one-third of the vertical height of the wall.

Fig. 3 shows a rectangular wall nine feet high and three feet thick, sustaining



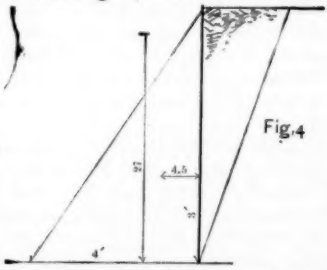
a bank of earth the density of which we will suppose equal to that of the material of which the wall is built, and of which the natural tangent of the angle of rupture is equal to 0.333: this tangent corresponds to an angle of about $18\frac{1}{2}°$, which in turn corresponds to a natural slope of about 37°. Considering a foot's length of wall, and taking the weight of a cubic foot of earth or wall as unity, we have a pressure of $\frac{13.5}{3}=4.5$ tending to produce slipping at the base, and a moment of $4.5 \times 3 = 13.5$ tending to produce overthrow.

Apart from the cohesion of the cement and the bond of the material, the resistance of the wall to slipping is its friction, which depends directly on its weight. As, in the comparison we are about to make, the relative frictions are all we care about, we will entirely ignore the co-efficient of friction, and consider only the variable factor, namely, the weight. We have in the present case a weight of wall equal to $9 \times 3 = 27$, giving a resistance as 6 to 1 as compared with the pressure tending to produce sliding.

The resisting moment of the wall to overthrow, neglecting cohesion of cement, is the weight of the same multiplied by the distance of the center of gravity, from the point around which it tends to turn. It is in the present case $27 \times 1.5 = 40.5$, or as 3 to 1, as compared with the overturning moment.

We have thus obtained the forces and resistances tending to produce or prevent sliding and overthrow at the base of the wall. If now we consider these forces and resistances as applied to the upper half of the wall, we will find that while the resistances are diminished by one-half only, the force tending to produce sliding is reduced to one-quarter, and that tending to produce overthrow to one-eighth, of their respective values as applied to the whole wall, and that therefore the wall is badly proportioned in that the destructive and resisting forces do not diminish in the same ratio.

Transforming the rectangular section of wall into the equivalent triangle shown in Fig. 4, we have the same de-



structive forces as before, and the same resistance to sliding at the base, *i. e.* as 6 to 1, while the resistance to overthrow at the base is increased from the fact that the center of gravity of the wall has been thrown further away from the point of rotation; it becomes $27 \times 4 = 108$, or as 8 to 1, compared with the moment tending to produce overthrow.

If, as before, we now consider the condition of stability of the upper half of the wall, we find as before the destructive forces decreased respectively to $\frac{1}{4}$ and $\frac{1}{8}$ of their whole values, while the resistances are diminished in exactly the same ratio. We may, therefore, conclude that the wall is well proportioned, and we see moreover, that while its resistance to sliding, due to its friction, remains the same as in the rectangular design, its resistance to overthrow has, by a mere change of form, been increased

as 8 to 3. It must be borne in mind, too, that the above resistance to sliding is only that due to friction. The bond of the material and the cohesion of the cement are also resisting elements, and the wall shown, Fig. 4, has a double width of base and, consequently, as far as bond and cohesion are concerned, a double resistance to sliding at the base.

If we suppose the density of the two walls, Figs. 3 and 4, doubled, making their weight 54, and carry out the calculation, we find that the ratio of eight to three remains unaltered.

Let us now consider the transformation shown in Fig. 5. With an equal

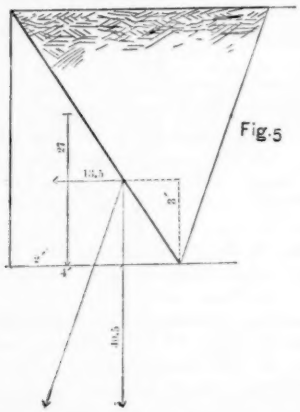


Fig. 5

weight of wall, we have here a weight of earth of 40.5, which, it must be observed, increases the stability of the wall at the same time that it increases the pressures against it.

Thus, we have a pressure tending to produce sliding of 13.5, with a combined weight of wall and earth tending to resist it, of 67.5, or as 5 to 1; and an overturning moment of 40.5, with a resisting moment due to weight of wall and earth with their respective leverages, of $27\times2+40.5\times4=216$, or as 5.33 to 1: a marked inferiority in both respects to the previous design. Doubling the weight of wall, gives a resistance to sliding increased to 7 to 1 only, and a resisting moment increased only to 6.66 to 1, showing that the ratio of stability increases much less rapidly than the weight of wall, unlike the previous examples where it increased as the weight of wall.

One important fact must, however, be borne in mind, respecting walls which, like Fig. 5, have the batter toward the bank, viz.: under certain circumstances overturning is impossible, because the overturning moment is derived directly from the weight of earth, and in such designs this weight forms at the same time a moment in favor of stability. In the above case, the moment of the horizontal component of this weight, tending to produce overthrow is $13.5\times3=40.5$, and the moment of the vertical component tending to prevent it, is $40.5\times4=162$. Clearly, in this case, and with these angles of batter and rupture, overturning is impossible, and the wall can only yield by sliding. At the same time the pressure on the foundations is increased.

In Fig. 6 we have the same ratios of resistance to sliding and overthrow as in Fig. 4. Doubling the weight of wall, however, gives increased ratios of stability of only 9 to 1 and 11 to 1 against

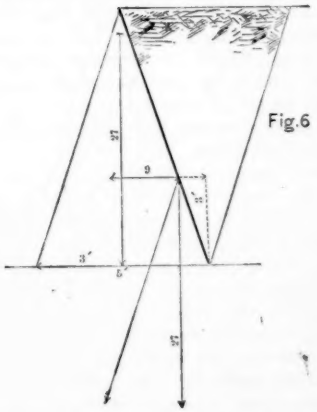


Fig. 6

sliding and overthrow respectively, instead of 12 to 1 and 16 to 1, as in Fig. 4. The same remark as to impossibility of overturning, as was made for Fig. 5, holds good here.

Both this and the preceding design are well proportioned as regards uniformity of resistance through their whole heights.

The above figures are to be considered as diagrams only, and not as representing proper designs for retaining walls. For instance, in an actual wall, the section would never be triangular but trapezoidal, and in the case of a wall battering

toward the bank, the sloping face would be stepped, instead of showing an even surface.

In the case of sections presenting a vertical face to the bank, no account has been taken of the downward pressure of the earth, friction against the back of the wall having been entirely disregarded. In practice, however, the back is left rough, and from its friction and hold on the earth would utilize a portion of the downward pressure in the interest of stability.

A wall tipped over toward the bank at an angle equal to the angle of pressure would sustain, theoretically, no thrust whatever. As, however, the angle of pressure must be considered as constantly varying with the hygrometric and other conditions of the soil, and is at all times more or less uncertain, a wall so built might, and probably would, be subjected to a varying uplifting stress, more injurious than a varying horizontal or downward one. Very admirable walls have been built upon this principle, and they well merit study. It would seem as a condition of primary importance, that, under no circumstances, should the wall be tilted over its center of gravity, so as to depend for support upon the earth behind it.

Buttresses, counterforts, relieving arches, etc., form subjects for separate investigation, and cannot now be considered. One word, however, may here be said regarding counterforts. Though not increasing the moment of stability of the wall to the same extent as buttresses, they notably diminish the moment of overthrow, by reducing the volume of sliding earth by the space which they themselves occupy, and by the side slopes which their friction generate, and, moreover, break the continuity of pressure, making it act only at detached points.

It is a matter of remark, that retaining walls generally possess a greater actual stability than calculation would indicate. When this occurs, it shows that the destructive forces have been over-rated. Indeed, it is only necessary to observe the length of time which many unprotected banks take before assuming their permanent natural shape, to be convinced of the great margin of safety included in the usual supposition that the pressure of the earth is applied instantaneously to the wall, and over its entire length.

Walls sustaining a surcharge of earth, *i. e.* walls placed at the foot of a sloping bank, involve a very intricate problem. One view of the question would seem to indicate clearly that the wall undergoes no greater pressure from the surcharge than if the bank of earth were terminated by a horizontal plane level with the top of the wall. Thus, let A B, Fig. 7,

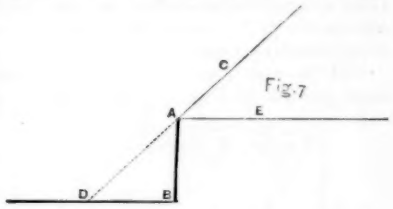


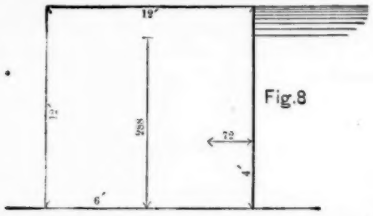
Fig. 7

represent a wall at the foot of a slope extending indefinitely in the direction A C. If the wall were removed, and the slope continued along the dotted line A D, the bank would of course stand, the angle C D B, being supposed to be as small as or smaller than the angle of natural slope. Consequently the necessary sustaining power of the wall must be equivalent to the prism of earth of base A D B. If now we suppose all the bank removed above the horizontal line A E, level with the top of the wall, we still find the prism A D B, necessary to sustain the bank E A B. That is, in both cases of surcharge and no surcharge, the same force is necessary and sufficient to sustain the bank.

This reasoning seems conclusive, and yet few engineers would probably feel justified in making no provision for an increased pressure due to the bank C A E. At all events, the pressure on the wall A B would be that due to the mass of earth which would detach itself if the wall were suddenly removed, and perhaps the safest plan is to suppose the line of rupture produced till it intersects with the slope of the surcharge, as shown by the dotted lines in Fig. 3, and consider this increased prism as that pressing against the wall. Should the surcharge extend to the front face of the wall, as shown by the lines *a b* Fig. 3, the weight of the prism *a b c* may be considered as added to that of the wall.

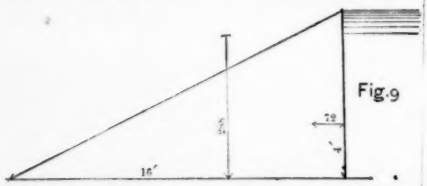
It will be interesting now to investigate some of the simpler forms of walls designed to sustain the pressure of a head of water. This pressure acts somewhat differently from that of a bank of earth, but as regards calculation, has the advantage of being determinate both in force and direction.

Let Fig. 8 represent the vertical section of a dam or reservoir wall, 12 feet by 12 feet. Let a cubic foot of water



be the unit of weight, and suppose the density of the wall to be double that of the water. Taking always a foot's length of wall, there is a pressure upon it equal to the weight of a column of water of 12 square feet base, 6 feet in height, acting perpendicularly to the inside face of the wall, and at one-third of its height from the base. The overturning moment is then $12\times6\times4=288$. The resisting moment of the wall is, by our supposition, regarding its weight, $12\times12\times2\times6=1728$. Ratio of moments, $\frac{288}{1728}$, or as 1 to 6. The pressure tending to produce sliding at the base, is 72. Weight of wall resisting same, 288. Ratio, 1 to 4.

Transforming the rectangle of Fig. 8 into the equivalent triangle Fig. 9, we

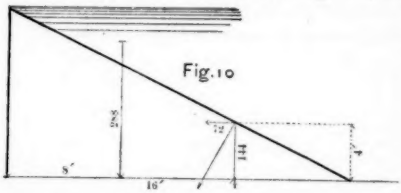


have overturning moment 288, as before, resisting moment, 288×16. Ratio, 1 to 16, or, as compared with previous ratio, 8 to 3. Resistance to sliding as before, with, however, the advantage of greater depth of bed.

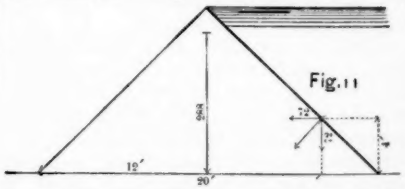
If, now, we calculate the destructive and resisting force upon the upper half of Fig. 8, we find that while the forces tending to produce sliding and overturning, are reduced respectively to one-fourth and one-eighth of their whole values, the resistance to both is only diminished to one-half, showing a redundant strength in the upper courses, as compared to the bottom course.

Calculating in the same way for Fig. 9, we find the destructive and resisting forces diminish in the same ratio, thus indicating a well proportioned design.

In the equivalent section, Fig. 10, we



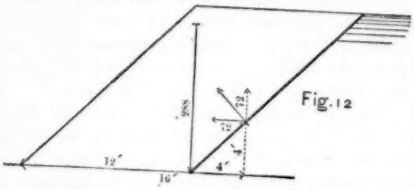
develop a vertical component tending to increase the stability of the wall, at the price, however, of an increased pressure on the foundation. When a certain head of water presses upon an inclined surface, as in Fig. 10, its horizontal thrust is given by the vertical projection of the submerged surface, multiplied by half the head, and the vertical pressure is given by the horizontal projection of the submerged surface, multiplied by half the head. We have thus, 72 and 144, respectively, for these two pressures. They give, a sliding pressure of 72, with a resistance to same from weight of wall and water of 432, ratio 1 to 6; and an overturning moment of 288 with resisting moments of 288×8



$+144\times16=4608$, ratio 1 to 16. Though we have calculated the overturning moment and the resistance to it, it is evident that the wall shown in Fig. 10 could never overturn, but could only be destroyed be crushing or sliding. Its resistance to the latter is greater than in either of the previous designs.

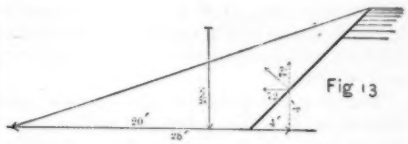
Passing to the design of Fig. 11, we

have, tendency to slide, 72, resistance to same, 360, ratio 1 to 5. Overturning moment, 288, sum of resisting moments,



4896, ratio 1 to 17. Here again, overturn is impossible, on account of the downward pressure of the water.

In such designs as those shown in Figs. 12 and 13 there is a tendency to



"blow up," from the vertical component of the water pressure. The data given on these figures, will suffice for their calculation.

CORROSION OF BOILERS.*

By Mr. F. J. ROWAN.

From one or two causes, corrosion has been found to attack the exterior surfaces of boilers, and eventually to work considerable damage. This, however, is a simple matter, as the action in these cases is easily preventible.

Thus, in the case of land boilers, careless setting in too much lime, has produced bad effects—the part of the boiler shell exposed to the, probably impure, lime having been eaten away to a large extent.

Setting the boilers upon a damp foundation without proper provision for draining, has also resulted in rapid destruction, whether the moisture reached the boilers through the lime of the setting or through the ashes.

Both marine and land boilers have been seriously corroded by ashes when cold having been carelessly allowed to remain in contact with the iron. The ashes contain a considerable quantity of alkaline salts of some strength, and with damp drawn from the bilge water in vessels, or from the ground ashore, or by deliquescence from the atmosphere, these salts have been enabled to attack the iron vigorously.

It has also been found by S. Dana Hayes (*Chem. News*, vol. xxx., 153, *Jour. Chem. Soc.*, vol. xiii., p. 294), that the soot in tubes and flues has become charged with pyroligneous acid, where wood has been freely used in lighting fires, or large quantities of coal have been charged at a time; and that this combination has caused corrosion. The same result has been caused by the soot retaining fine dust of ashes, and in consequence also sulphur acids, derived from pyrites in the coal. A case of this kind is also published by J. W. Chalmers Harvey, in *Chem. News*, xxxii., 252, *Chem. Soc. Jour.*, No. clxi., p. 796.

It is sufficient, however, to point out these causes, for they suggest their own remedies. Care in preparing and completing the setting, in cleaning flues and ash pits, and in firing being all that is necessary to prevent corrosion from them.

The injudicious use of brass cocks and connections bolted or fastened directly to the boiler shell, has often resulted in corrosion from galvanic action at the places where the two metals come in contact. This action proceeds more rapidly when a little leakage of water takes place at the joint or connection.

The operation of corroding forces in the interior of boilers, is, however, far more serious and baffling. Yet even these forces may be reduced to submission, but they demand study in the becoming spirit of patient enquiry.

* A paper read before the British Association at Glasgow.

Many investigations of these forces and their actions have been made, and it is advisable to review these before attempting to deal with the subject from an engineering point.

One of the first to publish experiments and trials connected with the corrosion of metals was the late Prof. Crace Calvert, who exposed iron and steel (with other metals) to the action of sea-water, of natural fresh water, and of distilled water, with and without air. He also submitted iron and steel to the action of various gases, with and without moisture, and to that of various acids. In general the results obtained by him showed that steel and then iron were most rapidly corroded by sea water when simply immersed in the sea for a time. (105.31 grammes of steel and 99.30 of iron being dissolved from plates of forty centimeters square by immersion in the sea for one month.) Also that iron immersed in water containing carbonic acid oxidised rapidly with escape of hydrogen gas, which led him to suppose that some galvanic action had part in the operation. He may, however, have meant merely thus to designate the decomposition of a part of the water by which oxygen was dissociated and combined with the iron under the influence of the carbonic acid. The corrosive action of carbonic acid was corroborated by his experiments with gases, for when bright blades of steel and iron had been exposed for four months to the action of various gases he obtained the following results: There was no oxidation with dry oxygen: with damp oxygen, one blade only out of three experiments was slightly oxidised: no oxidation with dry carbonic acid; with damp carbonic acid there was a formation of white carbonate of iron on the blades; no oxidation with dry carbonic acid and oxygen, but very rapid oxidation with damp carbonic acid and oxygen. He also found that distilled water which did not contain air or gases was without corrosive action upon iron, a bright blade which was immersed in such water having become in some days merely here and there spotted with rust. It was found that at these spots where oxidation had taken place, there were impurities in the iron which had induced galvanic action, "just as a mere trace of zinc placed on one end of the blade would establish a voltaic current."

An analogous action of distilled water with and without air was observed in his experiments with lead—200 litres of distilled water without air having dissolved during eight weeks only 1.829 grammes from a surface of 1 sq. meter, while the same quantity of distilled water aërated dissolved in the same time 110.003 grammes.*

These investigations were made the basis of an enquiry by Mr. W. Kent, of the Stevens Institute of Technology, into the corrosion of iron in railway bridges in the U. S., and by their means he was enabled to arrive at a satisfactory demonstration of the causes of the action. His paper was published in the *Engineer*, in Aug., 1875.

Recently, some of Calvert's results have been verified by A. Wagner, who publishes (in *Dingler's Polyt. Jour.*, 218.70-79) an important paper on the Influence of Various Solutions on the Rusting of Iron. Distilled water free from air does not appear to have been tested, but with air freed chemically from all carbonic acid, a slight rusting was noticed, the water, however, soon becoming saturated with its proper quantity of iron. The action of carbonic acid (or carbon dioxide) observed by Calvert is also noted, and the fact noticed for the first time that the presence of chlorides of magnesium, ammonium, sodium, potassium, barium, and calcium in the water largely increases the production of rust, while this important fact also appears from his results, that the corrosive action of all these substances is considerably increased by the presence of air and carbonic acid in solution. Chloride of magnesium of all these salts is the most active agent when alone in corroding the iron, but combinations of chloride of magnesium and carbonate of lime, of chlorides of barium and calcium, and of chlorides of sodium and calcium have also considerable corrosive action.

This to some extent corresponds with

* Sir R. Christison has made investigations into the action of water on lead (*Chemical News*, vol. xxviii. 15), but seems in his conclusions not to have distinguished between distilled water and pure natural waters, merely comparing them with respect to *purity*. Yet the fact that he always found carbonate of lead formed by the action of the purest waters suggest that the action was due to the presence of gases in solution and not to the water itself.

the fact observed by Mr. John Gamgee, as a difficulty which he had to encounter in connection with the continuous freezing of water for his "Glaciarium," viz, that the brine solutions used as media of congelation act destructively upon the metallic surfaces of the pipes or channels through which they are conveyed. (*Engineering.* vol xxi., page 226.)

Wagner, however, has also noticed that while chloride of magnesium solution in the absence of air attacked iron at a temperattre of about 100° Cent., the chlorides of sodium, potassium, barium and calcium were without action under these circumstances. This author also notices the fact, the observance of which is ascribed to Mr. Young, of Kelly (in a paper read by Mr. James R. Napier before the Phil. Society of Glasgow, Dec. 16th, 1874), viz., that the presence of an alkali in water protects iron and prevents rusting. In consequence of the great importance of his results, I give two tables of figures (from the four contained in his paper) representing some of them :

No.	Solution.	Percentage of loss of weight in one week.	
		With air free from CO_2.	With air and CO_2.
1	Freshly distilled water	0.83	1.53
2	Containing Ba Cl_2 and Ca Cl_2	1.63	1.46
3	Containing Na Cl and KCl	1.20	2.03
4	Containing Mg Cl_2	1.40	1.85
5	Containing NH_4 Cl	1.29	2.16
6	Containing $K(OH)_2$	—	—
7	Containing Na CO_3	—	—
8	Containing sea water	1.26	1.02
9	Containing sea water, evaporated, and oil 5 drops	0.47	0.73

No.	Solutions.	Boiling in contact with air then and while cooling. Percentage of loss of weight—					
		1 week	2 wks.	3 wks.	4 wks.	5 wks.	6 wks.
1	Distilled water	0.44	0.82	1.15	1.53	2.02	2.46
2	Flask half-filled with distilled water —*i.e.*, more air	1.01	1.62	2.75	3.68	4.53	5.18
3	Containing Ba Cl_2 and $CaCl_2$	0.66	1.33	1.57	1.82	2.03	2.27
4	Containing Na Cl and KCl	0.84	1.47	2.15	2 57	3.04	3.41
5	Containing Mg Cl_2	1.31	1.91	2.20	2.49	2.76	3.05
6	Containing Mg Cl_2 and excess of Ca CO_3	0.89	1.54	2.08	2.46	2.97	3.27
7	Containing NH_4 Cl	1.15	1.86	2.56	3.16	3.66	4.16
8	Containing $K(OH)_2$	—	—	—	—	—	—
9	Containing Na CO_3	—	—	—	—	—	—
10	Sea water	0.43	0.65	0 70	0.75	0.97	1.24
11	Sea water and Ba Cl_2	0.15	0.46	0.69	0.92	1.08	1.23
12	Sea water and 10 drops oil	0.59	0.59	0.62	0.72	0.83	0.93

I quote here an important experiment made by him on the effect of chloride of magnesium on iron at boiling temperature.

Two grammes of neutral magnesic chloride were introduced into a strong tube in which weighed pieces of iron were placed; boiling distilled water was

added, and the tube sealed up while steam was issuing. It was then kept at 100° Cent. (212° F.) for six weeks, and after cooling was opened. Gas was evolved on opening it; the iron was black and had lost 0.39 per cent. in weight, and the solution when filtered contained chloride of iron (ferrous chloride). (*Dingler's P. J.*, ccxviii. 70-79. *Chem. Soc. J.*, No. clx. p. 522.)

Still another valuable contribution to our knowledge of this subject comes to us from Germany, in the results of an examination of the effects of condensed water containing grease on boilers which were fed with it, by Stingl, an author who also proposed and successfully carried out a method for the purification of that water.

The water was evidently condensed by means of an injection condenser, as salts of lime and magnesia were present in small quantity in the condensed water. These salts, in presence of grease, at a temperature not exceeding 60° to 70° C., form lime-soap—part of the lime salts being, as has already been shown, rendered insoluble at these temperatures. The lime-soap, under the influence of a higher temperature, partially decomposes into free fat acid and an organic substance which is reducible by further heat, yielding a carbonaceous residue. This substance is a kind of basic lime-soap which adheres to the boiler surfaces, while the acid, which is usually oleic acid, attacks and dissolves the iron. In the crust the fat acid is recognised by the addition of hydrochloric acid, the separated organic mass being afterwards shaken with ether. The boiler crusts have usually a dark color, partially due to the presence of oxide of iron, partly to separation of carbon from the fat acid partially decomposed. Even if lime and magnesia salts are present in very insignificant proportion, the presence of grease is none the less injurious, as with saponification under great pressure, a very small quantity of lime suffices to occasion the splitting up of a neutral fat into free fat acid and glycerin; with low pressure it is not doubted that the same decomposition occurs, though more gradually.

A sample of very soft water (6° of hardness) depositing very little crust, was submitted to the author of that paper, as a boiler in which it had been used was completely destroyed after three years' work. This water had a milky appearance, and contained 0.212 parts of fat in one litre.

He also quotes the case of the corrosion of a gasometer, the cistern of which had been luted with greasy condensation water. The gasometer would have lasted twenty or thirty years had ordinary water been used, but in the circumstances mentioned, that part of it exposed to the water was corroded through after four years.

The destructive action of the oleic acid on the oil-pumps used in stearin candle manufactories is also alluded to. And the following details are given of an interesting case of boiler corrosion, with accompanying incrustation, and of the means used to overcome the destructive action. The condensed water from two steam engines, respectively of 300 and 100 horse-power, was used to feed a steel boiler of the Cornish design. After only three weeks' firing, water began to leak into the tubes, and shortly after the boiler had to be stopped for examination and repair. A deposit on the upper part of the tubes, from eight to eleven mm. thick, was found. The water had an opalescent appearance, at once removed by ether, which the author recommends as a good qualitative test for the presence of grease in water. The following is the result of analysis of the condensed water, which was obtained at a temperature of 40° to 50°.

	In 10,000 parts.
Calcium carbonate.....	1.3091 "
Magnesium carbonate.....	0.6930 "
Calcium sulphate.....	0.3158 "
Magnesium chloride.....	0.0134 "
Sodium chloride.....	0.1200 "
Ferric oxide and alumina...	0.0241 "
Silica.....	0.0023 "
Organic matter.....	0.4138 "
Total.....	2.8915 "

The crust deposited from this water had a dark greyish-brown color and was friable; but when pulverised it was difficult to wet with water. It effervesced strongly with hydrochloric acids, a black fatty mass being left floating on the surface of the acid, which shaken with ether yielded thereto about 5.19 per cent. of a brown oil. The residue insoluble in hydrochloric acid was washed with ether

to remove fat, dried at 100°, weighed and ignited. The following shows the full analysis:

Calcium carbonate	51.42	per cent.
Magnesium carbonate	11.30	"
Magnesium hydrate	3.90	"
Calcium sulphate	6.63	"
Ferric oxide	12.75	"
Alumina	0.31	"
Silica	0.34	"
Fat acids	5.19	"
Combustible matter	8.46	"
	100.30	

In order to purify the water, the calcium carbonate and part of the magnesium carbonate, with all the grease, were removed by precipitation and subsequent filtering. The fat particles were removed by being enveloped by the precipitated calcium carbonate, which mechanically retained them on the filter, the reaction being favored by suitable temperature and intimate mixture previous to filtering.

The water then contained in	10,000	parts.
Calcium carbonate	0.1773	"
Magnesium carbonate	0.4135	"
Calcium sulphate	0.2068	"
Magnesium chloride	0.0108	"
Sodium chloride	0.2351	"
Silica	traces.	
Ferric oxide and alumina	traces.	
Organic matter	0.1512	"
Total	1.1947	parts.

No grease could be detected in the filtered water, which was then used in the same boiler, after being repaired, for three months, when the deposit on the tubes was found to amount to a layer of only the thickness of a sheet of paper and almost wholly consisted of gypsum, and easy to remove. The whole amounted to only five kilometers in weight after three months' steady work. It was a loose greyish-brown mass, the following showing the analysis:

Calcium carbonate	19.30	per cent.
Magnesium carbonate	1.26	"
Magnesium hydrate	45.02	"
Calcium sulphate	15.12	"
Ferric oxide	9.43	"
Silica	2.04	"
Organic matter (insol. in ether)	7.35	"
Fatty matter	traces.	
	99.52	

To purify such water as the above-named for high pressure boilers, a mixture of lime-water and caustic soda solution is recommended, as this not only removes fat acids but also removes the magnesia, which forms with gypsum hard incrustations at high temperatures. (*Dingler Polyt. J.*, ccxv. 115-121, *Chem. Soc. J.*, vol. xiv., sec. 2. p. 132.)

In a letter on the corrosion of boilers, addressed by me in October, 1874, to the Editor of *Engineering* (and published in that paper on October 23, 1874), reference was made to the Report on Corrosion of the Tubing of two of Rowan & Horton's Patent Boilers, by Mr. Thomas Spencer, an analytical chemist. Starting from the slender basis afforded by the examination of water mains in two cases of internal corrosion of these, where a very pure natural water was conveyed through them, Mr. Spencer argued that the corrosion in these boilers was due to the use of distilled water, which alone was used in them, but which he confounded with pure natural water. In the absence of any well ascertained facts as to boiler corrosion, his opinion was accepted as sufficiently explanatory of the action; but, as is often the case with half-knowledge, that which was true in his investigations, was rendered indistinct by crude conjectures. In consequence of this, in the letter referred to, and generally in all published opinions emanating from engineering sources which I have seen, neither the great difference between genuine distilled water and pure natural waters—viz., the quantity of air and gas which is invariably held by the latter—has been properly weighed or even acknowledged, nor has the only point of similarity between the distilled water from surface condensers known on board steamers and pure fresh water—viz., that there is always some air present in the former—been noticed or allowed for. In the letter referred to, I regret that I was misled into confounding distilled water with Loch Katrine water, having in view merely purity, and not considering the presence of air or gases.

In considering now some examples of boiler corrosion, I shall adopt the arrangement already used in the section on Incrustation, viz:

1. Land boilers using natural fresh waters; and,
2. Marine boilers.

1. From what has been before us in connection with Incrustation, it is plain that it is in those land boilers only which are fed with pure natural waters that we are likely to find Corrosion at work. Where lime salts are present, a crust is formed, and the metal surfaces of the interior of the boiler are thus kept from contact with the water and any corroding ingredient in it. The special inconveniences of such crust formation we have already considered. Highly chalybeate waters, although not depositing a crust, do not seem to act injuriously. A case is mentioned in Mr. Jas. Napier's paper in *Proc. Phil. Soc. G.*, demonstrating this. There may, however, be some material forming part of the crust, or adhering to it, which suffers decomposition in contact with the heated iron, and, as a consequence, attacks the metal. This is the case with crusts formed with fat or greasy substances, as in the instance already quoted in the paper by Stingl.

We have, in this district, ample opportunity of proving the effect of very pure fresh water upon boilers, because there are few natural waters of greater purity than that from Loch Katrine, with which various manufactories in and around this city are supplied.

The water formerly supplied to Glasgow having been calcareous, it has been found that boilers which used it for some time, have not suffered from corrosion when subsequently fed with Loch Katrine water—the explanation of this being the fact that the thin coating of lime which these boilers had acquired acted as an efficient and permanent protection.

Where, however, owners or managers have been very zealous in removing by mechanical or chemical means every trace of that crust in order to get the full benefit, as they have thought, of the pure water, the result has been different and "the full benefit" has often been of a kind to perplex them. When also new boilers have been started from the first with Loch Katrine water corrosion has been more or less rapid, and considerable trouble and inconvenience have been caused thereby.

These facts find illustration in many manufacturing establishments around. I have been informed, amongst others, of a boiler attached to a mill in Bridgeton where every care was taken to remove all scale before introducing Loch Katrine water, and the millowners were chagrined by finding their boiler quickly suffer from corrosion.

In an engineering work at Port-Dundas (Rowan & Co.'s), one boiler which had wrought upon a supply of the former calcareous water, and was latterly supplied with Loch Katrine without being scaled, continued to work for some years without showing symptoms of distress from corrosion. In the same works, however, a range of new boilers, put down after the introduction of the pure water, suffered so severely as to require constant repairs at tubes, and an entire new set of tubes (of between forty and fifty in each boiler) in a comparatively short time. In another engineering work on the south side of the city (A. & W. Smith & Co.'s), the mains hop boiler was worked for three or four years without suffering corrosion with Loch Katrine water, after having worked previously for seven or eight years with the former Glasgow water. When a new boiler was substituted for this old one, although the new one was subjected to precisely the same conditions as those its predecessor wrought under for some years without trouble or difficulty, it was found to the consternation of the proprietors that the new boiler was corroding away so fast as to suggest that a third boiler would be required very soon. Until the presence and effect of the lime coating in the former boiler were pointed out, it was impossible for them to understand how one boiler should be able to use Loch Katrine water without damage, while another similarly worked should suffer in so short a time.

In the former of these two examples no condensed water was fed into the boilers, as they were working in connection with high pressure atmospheric engines and other machines; consequently there was no grease or other corrosive agent introduced into them, and thus the corrosion could be traced directly to the water. In the latter one, a part of the condensed steam was collected in the feed cistern, and a considerable quantity of grease thus found its way into the boiler, thus aiding the corrosion somewhat. Steps were at first taken to ex-

clude this grease from the boiler but the corrosion afterwards proceeded—large quantities of oxide of iron being removed from the boiler—until means were adopted to overcome the action.

The following is the result of the analysis of the water made during July, and published by Prof. Mills, who informs me that it represents a fair average of the quality of the Loch Katrine supply:

	In 100,000 parts.
Total solid impurity	3.16
Organic Carbon	0.110
Organic Nitrogen	0.033
Ammonia	—
Nitrogen as nitrates and nitrites	—
Total combined Nitrogen	0.033
Chlorine	0.70
Hardness	0.48

The report also bears that the water was pale brown in color and contained traces of fibrous matter and muddy particles, and that the general condition was very satisfactory.

Nothing contained in the water as impurity can account for its destructive action; but the fact that it contains seven to eight cubic inches of gas (of which about three cubic inches are oxygen) to the gallon in solution, coupled with the investigations already quoted in this paper, as to the effect of distilled water without gas and of water containing gas, makes all plain. The corrosion is due to the action of the carbonic acid and oxygen held by the water, and the action is all the more rapid, from the absence from the water of any mineral matter with which the gases can combine. In both of these engineering works an artificial coating of lime was formed in the interior of the boilers, by feeding regularly into them each morning for some time a whitewash of Irish lime and water. This expedient was quite successful in checking the corrosive action, and as the lime soon hardened, under the influence of the heat, no trouble was experienced in preserving the coating. Pieces of limestone were also placed in the feed tank or cistern, but it is doubtful if they produced much effect. The carrying out of the application of lime in this way, was due to the ingenuity of Mr. T. R. Horton. Where, however, it is possible to mix with Loch Katrine or other pure water, a proportion of a calcareous natural water for a time, the scale formed thus in working will probably be of a more enduring nature. I strongly recommend this plan to those using Loch Katrine water, who have access to former sources of supply.

2. Marine Boilers. We are introduced to a variety of corrosive actions in considering marine boilers, according as we have to deal with boilers working with nothing but fresh water or those which use a proportion of sea water. It is necessary, however, clearly to distinguish these two classes.

The only marine boilers as yet using exclusively fresh water in regular working with which I am acquainted are those of Rowan & Horton's, mentioned in the letter to *Engineering*, to which I have referred, and elsewhere, and those working on Perkins' plan. Some of the ordinary boilers used in steamers with what are called compound engines, have been occasionally wrought entirely with fresh water, but in every such case recorded, that manner of working was abandoned after a very short trial, in consequence of the rapid corrosion which was discovered to be going on. Boilers in vessels whose voyages are always made in sea water, are constantly liable to receive a small quantity of salt water by leakage through surface condenser joints, or some other connections, so that even where it is or has been the intention to use fresh water only, it is not possible without analysis to determine if that has been done. The first of the examples quoted above have, however, this element of uncertainty removed from their case in consequence of their steamers running in fresh water, except for a very small part of their voyage. In their case corrosion from fat acids and from galvanic action, of what may be called an intermittent kind, was experienced and successfully counteracted. These actions, and the respective remedies which were adopted, I have mentioned in the published letter referred to, and I quote them here because they show what are the corrosive forces to which marine boilers, working exclusively with fresh water, may be subjected. Lime was present in small quantity in the river water used to fill up the boilers at starting and to make up waste in working, so that the decomposition of fats already described could take place. When the

grease was removed as much as possible by filtering the feed water, and the presence of any free acid neutralised by zinc the corrosion ceased. The galvanic action was also arrested by means of the filter, because in general this action is caused by local contact with particles of metal carried into the boiler, and not, as has been erroneously supposed, by means of the surface condenser and the boiler forming together the two elements of a huge battery, the steam and water being the exciting medium.

Of Perkins' boilers worked in steamers, we have no published accounts with which I am acquainted, so that we cannot say whether they have suffered from corrosion in the course of the exigencies of practical voyage making. It is, I know, the aim of Mr. Perkins to exclude if possible all sea water, and all oily matter from his boilers, and if successful in doing this, and working only with fresh water, the corrosion will not be great. Still there will be some, as the gases of the natural fresh water with which the boilers are filled at starting will oxidise their proportion of iron, and in the feed water, which, as condensed steam has been returned from engines through the surface condenser and discharged by the air pump into the hot well, there is of necessity (probably not much), yet some air present, as the condensation takes place in contact with air; and this air will also do its own share in corroding fresh portions of the clean surface of the boilers. It is probable that if these boilers are introduced into merchant steamers and become subject to the invariable emergencies of regular trading by which leakages, deficient supply, and contamination of feed water are experienced, and foreign substances find their way into the boilers, the evils of corrosion may be known to a greater extent than that to which they reach, where it is possible to observe all the precautions of the inventor of that system.

Generating steam from fresh water alone is undoubtedly the proper, as it is sure on this account to be ultimately the general, mode of operation with steam boilers, but for ordinary sea-going purposes, appliances must not be too delicate, but require to possess the power to endure abnormal and adverse conditions.

The case of a coasting steamer using in her boilers natural fresh water from two sources (one at each end of her voyage) whose boilers were destroyed by corrosion with great rapidity was made known by Mr. James Gilchrist, in a paper read before the graduate section of the Inst. of Engineers in Scotland, and published in February of this year in a periodical called *Marine Engineering News*. Analysis of one of these waters (the other having been Loch Katrine), and of the deposit found in the boilers are given in the paper with the opinions of two professional chemists, who ascribed the corrosive action to the injudicious use of a large quantity of tallow in engines and boilers. There is no doubt that the decomposition of the tallow was in itself sufficient to cause serious damage to the boilers in presence of fresh water containing a small quantity of lime; but the action in this case was modified by a fact not noticed by the chemists—viz., that during the voyage of the steamer all deficiency in feed water was made up from the sea. The boiler deposit consequently contains 9.11 % of magnesia, and 12 % of common salt, as well as 8.86 % of oil and organic matter; and it is to the presence and decomposition of chloride of magnesium to which the presence of magnesia in the deposit bears witness, as well as to the carbonic acid of the original boiler supply, that a great part, and probably the rapidity of the corrosive action, is, I believe, to be attributed.

This leads to the consideration of marine boilers using partly fresh and partly salt water, by far the most extensive class at present, and that which has suffered most from corrosive action.

A very intelligent account of the state of matters in this class of boilers is given by Mr. Milln, in a paper read before the Cleveland Iron Trade Foremen's Association, Nov., 1875, and published widely in the engineering periodicals. This author describes graphically the introduction of the surface condenser into marine engine practice, with which is coincident the commencement of all real trouble from corrosion, and he then describes the course of events with two distinct sets of marine boilers. In the

first of these we have a good example of boilers which had been worked at comparatively low pressure, viz., twenty-five pounds per square inch and fed for four years with sea water—working during that time in connection with an ordinary injection condenser attached to engines which indicated 900 horse power. As the voyage was not of long duration and time was given for regular "scaling" of the boiler surfaces (i.e. removing the scale from them) at the close of every voyage, no damage was done by incrustation and no inconvenience beyond the cost of fuel consumed was experienced. The injection condenser was then replaced by a surface condenser, some of the old incrustation being left adhering to the boiler surfaces, and the boilers were worked for some time thereafter with fresh water, the deficiency in feed supply being made up from the sea. The crust was soon removed and the boilers corroded, showing pits and blotches and all the usual symptoms.

The other instance quoted by Mr. Milln is that of a new set of boilers working at sixty-five pounds pressure in connection with compound engines of 1700 horse power and surface condenser, evidently an excellent example of average modern steamship machinery. These boilers were worked from the first with fresh water, the waste being supplied by distilled water, yet the density of the water increased daily and corrosion proceeded at the same time most energetically. After one voyage the boilers were filled at starting with sea water, but no more sea water was added during the voyage except the small quantity necessary for surplus feed supply. Under these fresh circumstances corrosion still proceeded, though it was thought more slowly, and was only finally stopped by what is called "changing the water," i.e. blowing off a quantity regularly and replacing it with sea water, thus introducing fresh quantities of sea water into the boilers during the voyage.

This author then alludes to the many theories explanatory of corrosive action which have been started, but only to reject them all and adopt the popular error, that corrosion is due to a change supposed to be wrought upon the water itself by distillation or re-distillation, which according to some, confers upon it the properties of a powerful solvent of metals, and according to others, although they do not like to state it thus plainly, this distillation decomposes the water and dissociates its oxygen, which forthwith attacks the iron of the boilers, or as Mr. Milln puts it: "the constituent elements of water when frequently redistilled undergo such a change as to greatly intensify its action on or affinity for iron," One engineering journal indeed very confidently affirms that it is "a fact but too familiar to engineers that the continuous boiling of distilled water in an iron vessel causes the destruction of that vessel," but has to admit that the circumstance that that water also passes over a very great surface of brass or copper, (of the destruction of which, however, not a word is said,) complicates the aspect of the phenomena.

It must, however, be confessed by engineers, that of the data or investigations by which so apparently wild a theory has been established as a fact they are as yet profoundly ignorant, and as Mr. Milln observes "it is with regard to the nature of this change that we so much want information!" There is this solitary fact known and harped upon, viz.: that dry steam in contact for a period of time with iron or carbon in a tolerably fine state of division and at a red heat is decomposed hydrogen gas escaping, while the oxygen combines with the iron or carbon. But this has never been attempted with water nor can be done with steam below red heat. What is known of the action of distilled water proves, indeed, the clean contrary to this theory, and in illustration of "what is known," I refer to those investigations which I have already quoted. They prove that it is the presence of air or gases which makes the difference in the action of various pure waters, and even in that of the various salts dissolved in impure waters, and that when water is distilled free from air, its corroding power is lost. Thus the remedy for corrosion proposed by some engineers to-day—viz., that the condensed steam should be aerated, proves to be a foolish suggestion, for this would but *increase* the power of that water to corrode the iron of the boilers.

I shall be within the strict truth when

I say that it is hasty to conclude, from examples of boiler corrosion, that distilled water has to do with the corrosion, for the fact is that there is no case known in which the proper effects due to the employment of distilled water alone, and free from gases, upon the metal of boilers, could have been observed. The boilers of Rowan & Horton, and of Perkins, present the nearest approach to the conditions requisite for such information, but not all the necessary conditions are found even in these instances. The examples just quoted from Mr. Milln's paper are of the kind with which engineers are more generally familiar, and they do not give such data as would lead to the conclusions about distilled water. The opinion is therefore due to a hasty conclusion, drawn from the coincident occurrence of corrosion with the introduction of surface condensers.

In the first example, genuine distilled water was never present. The boilers were filled up with fresh water at starting with the surface condensers, but not only was waste and deficiency of feed made up from the sea during the voyages, but there was also the saline crust adhering to the boilers to be dissolved or partially dissolved by the fresh water. Contrary to the opinion of Mr. Milln and others, I maintain that just because analysis shows that such crust contains chloride of sodium (in appreciable quantity when formed at such a pressure as that of the boiler mentioned—viz., 25 lbs. per square inch), if not also other soluble ingredients, a certain part of the crust must have been—and in such cases always is—dissolved; and thus the crust is partially disintegrated, and the insoluble magnesia and sulphate of lime fall in flakes to the bottom of the boiler. The fact that the water did not long remain fresh does not in any way interfere with this opinion, for it is a fact well known that salts dissolve more readily in a solution of other salts than in fresh water. Hence the scale would come off even more rapid when a small quantity of sea water was used.

The second example started with boilers filled with natural fresh water, which itself has (as we have seen), if pure, power to corrode by its gases in solution; but although distilled and not sea water in this case was used for surplus feed supply, the salinometer test showed plainly that pure distilled water was never present, and that either sea water was getting in through a leaky condenser, or that fatty and other matters were accumulating in the boiler, the color and taste of the water being decided indications that such (and probably *both* of these) results were happening. After the first voyage which gave such results, sea water was regularly used in greater or less proportion.

Thus we must search for the corroding agents apart from the distilled water. The analyses by Dr. Wallace and others, of boiler crusts, and the researches of Wagner and Fischer quoted herein, reveal one very important one—viz., the chlorine or hydrochloric acid set free by decomposition of the chloride of magnesium in the sea water. This decomposition may take place under the influence of high temperature alone, when magnesium hydrate is deposited, while the iron is attacked by the hydrochloric acid, first cloride and subsequently oxide being formed. As the combined influences of temperature and carbonate of lime are present, it is probable that the sulphate of magnesia is also decomposed, and that some oxychloride of magnesia is also formed, but this has not yet been demonstrated by analysis of deposits, though it is the opinion of Dr. Mills and others that part of the magnesia reported in ordinary analysis of boiler deposit from sea water exists in that form. Dr. Fischer also demonstrates that this mutual decomposition of magnesium sulphate with calcium carbonate is a fact, and that the liberation of carbonic acid also necessarily takes place.

The researches of J. Y. Buchanan "on the power of sea water to absorb carbonic acid," to which I have already referred, have shown us that sea water, on account of the sulphates which it holds in solution, absorbs a large amount of that gas, which it readily gives up on the sulphates being decomposed or separated from the water. Such decomposition and precipitation of sulphates occur in marine boilers, besides there being, now since the surface condenser era, repeated boiling of the water, which of itself in time liberates nearly all the carbonic acid. We have in these two agents, viz—the hydrochloric acid of the

decomposed chlorides and the carbonic acid, combined with high temperature and pressure, quite enough to account for most of the corrosion which occurs.

The researches of Stingl, which I have quoted, show the power for evil which greasy matters wield, and this specially I believe where the water is comparatively fresh, though not there alone. And where grease is allowed to reach the boilers it can also carry along with it particles of other metals, which, in spite of the incredulity of some engineers, have been found to do mischief, and are capable of doing, if possible, more in presence of salt water than with fresh, unless it be acidulated. It is not supposed that they can do *all* the mischief, or even any in places to which they cannot reach; it is sufficient that they are capable of doing some, and there are specimens extant (among the specimens collected by the Admiralty committee on boilers, for instance) of corrosion and abrasion of brass tubes and other parts of engines, which show that this is a real and not a fancied danger.

The simple explanation of the fact that all such corroding agents have done damage principally since the introduction of the surface condenser, is that the surface condenser, by separating the condensed steam from the sea water used to condense it, and by returning so much fresh water to the boilers, has reduced the proportion of sea water used in them below that point at which it is possible to form a protecting scale or crust by the saturation of a considerable quantity of sea-water. It also, as I have said, provides for the complete liberation, by repeated boiling, of the carbonic acid held by the sea-water.

That sea-water alone at the boiling point corrodes iron is proved by one of Wagner's experiments, in which the percentage of loss from a piece of iron plate which was kept in contact with boiling sea water and air for six weeks, steadily increased from 0.43% after one week to 1.24% after six weeks. And proof that in marine boilers a small proportion of sea water is capable of doing mischief while a large quantity is not, is found readily in the fact that engineers have repeatedly *arrested corrosive action* by simply increasing the quantity of sea-water in the boilers, but without altering any of the other conditions of working. It is always in boilers that are "worked fresh" (*i.e.*, with the minimum of sea-water) that corrosion proceeds most rapidly, and I know of one steamer (the S.S. Vespasian) where by continually working fresh, a new set of boiler tubes was required in little more than twelve months after starting, while after that time, in the same boilers, the use of a large proportion of sea-water was enough without further change in working to preserve the boilers from rapid corrosion. As soon as the smallest quantity of scale begins to form, destructive action is arrested. This is true of all the various kinds of destructive action, and explains how under the old regime none of these were known. It also shows how fallacious must be any conclusions drawn from comparisions of results with old boilers in any attempt to argue from them to results in modern ones, as though both were obtained under like conditions. Another proof of the existence of such decompositions as I have described is found in the fact that the water of boilers in which corrosion is going on becomes alkaline. This shows an accumulation in solution of the effect of the alkaline ingredients of the sea-water, by decomposition and the neutralisation of the acid ingredients, and it is for this reason that some have been disappointed by testing the water, who had concluded that if corrosion was due to the presence of acid substances then the water must be acid.

The pitting and blotching effects produced on the metal of the boilers prove on examination to be not so mysterious as our first apprehensions rendered them. The same results follow the use of corroding liquids in any metal vessels when exposed to air and to light. Even basins made of platinum, which is harder and closer in texture than any other metal, I am informed are found by chemists to wear in a similar way by having certain liquids boiled in them, and thus the effects are apparently due to non-homogeneity of the metals as well as to purity in some cases. Heat in most instances has a considerable share in directing the action which is usually found to have been more intense in the hotter regions.

Before adverting to a remedy for this action, I may say that in the boilers of

the S.S. Propontis, analyses of crusts from which are given previously, the various results of corrosion were experienced. Increase of density in the water observed when nominally working with fresh water alone, proves from the analysis of the deposite then taken from the boilers, and from an estimation of the total solids in the water at the close of that voyage (made by Mr. Tookey, and found to amount to 3272.5 grains in the gallon), to have been due to leakage of sea-water into the boilers by means of connections with a small boiler used for supplying steam to a cylinder steam-jacket. Milkiness and acrid taste in the water were no doubt due to the presence of fatty substances in solution, as a large quantity of grease was collected on the filter through which all the feed water passed. It is probable that these two causes will be found to account in nearly all cases for the increase of density often observed in similar circumstances of working.

It now remains to suggest a remedy. Much has been said in favor of the use of zinc in boilers, but zinc will not do where any proportion of sea-water is used, because it is very rapidly decomposed by the salts in sea-water, and chloride of zinc merely adds to the impurities and evils of the case. It has been, and may be, used successfully in fresh water, where there is free acid to be neutralized, but there its usefulness stops as far as corrosion is concerned.

Filtering the feed water is a most excellent precaution, and should undoubtedly be universally adopted in order to prevent, as far as possible, the entrance of foreign substances into the boilers.

To prevent the corrosive action in them of matters in solution, which no filter can arrest, I believe no better remedy can be found than the forming on the interior surfaces an artificial coating composed of calcium sulphate and magnesium hydrate in proportions varying according to the pressure carried in the boiler. This can be readily fed in, in the form of a thin whitewash with fresh water, and should be applied to all boilers on the very first occasions of getting up steam in them. Otherwise corrosive actions may commence, and unfit the surfaces for the adherence of such a protecting crust. A protecting crust has repeatedly been formed in boilers by using salt water; and in one of Mr. Milln's examples he was able to keep this of proper thinness by regularly blowing off about 1.9th of the water evaporated. Yet this is, as he admits, a very troublesome, and not a safe method of working, and yet to keep such a scale on, it must be carefully carried out without intermission, because as soon as the boilers are allowed to "work fresh" that scale dissolves off. By making an artificial scale with fresh water, as suggested, its thickness is quite under control, and when once hardened by heat, fresh water will not dissolve it, and thus steam can be generated in the best way. Even if a small quantity of sea-water should leak in it is not likely that the coating would be injured.

Apart from such a plan there seems to be no hope of escaping corrosion and advancing at the same time in engineering practice, until it is possible to have copper boilers. And yet, even then, as the recent experiments of Carnelley on "The action of water and of various saline solutions on copper," seem to show, we should still have to combat the same difficulties.

FORCE.

By DE VOLSON WOOD, M. A., C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

I HAD nearly completed an article upon this subject when I received the November number of the Magazine, in which is an abstract of a lecture by Professor Tait, upon the same subject. That article covers nearly the same ground as the one I had prepared, and many of the views presented are identically the same; still there are a few points to which I wish to call attention, and more particularly to the elementary idea of the measure of force.

It is conceded that technical terms should be as definite and limited as possible. They should not be ambiguous, though when used in different branches of science, the same word may represent different ideas. The common term *power* is used in Mechanics, Optics, Psychology, &c., and in each, it has its peculiar meaning. But in the same science the same term should not be applied to two distinct ideas. Force, in Mechanics, is defined to be "That which moves, or tends to move a body, or to change its rate of motion." That which tends to move a body without actually producing motion, is called *pressure*. Is pressure force? Can we properly distinguish between that agent which only tends to produce motion and that which actually produces it? Is the agent which produces motion equivalent to a pressure, or is it distinct from it? I wish to show that pressure, whether it produces motion or not is a physical manifestation of force, and that the forces of nature, such as attraction and repulsion, when they do not produce pressure are equivalent to a pressure and may be measured by the same units.

The general reader may at first suppose that I am raising an imaginary question, since the assumed distinction is not even suggested by the definition. But such is not the case, for certain English writers have clearly made the distinction. For instance, a few years since, during the discussion of a question before the "Institution of Engineers," one speaker remarked that much of the difficulty connected with the case arose from the fact that many writers made no distinction between *force* and *pressure*; that a force was that only which produced motion, and that pressure does not produce motion. Again, Price, an English author, in the introduction to the third volume of his "Infinitesimal Calculus," gives the usual definition of force, but in his introduction to Dynamics, he at least intimates that force is that which produces motion. Also Professor Tait, in the lecture referred to, defines a unit of force to be that which "In one second, gives to one pound of matter a velocity of one foot per second." This definition may be extended so as to be the measure of a *pressure*, by defining it to be that which would produce a velocity of one foot per second when acting upon a pound of matter perfectly free to move. Many other writers define the unit in the same way.

I will show hereafter that this is a correct unit, especially if the force be constant, but it is neither the simplest nor best. As we do not presume to know anything of the essential nature of *force*, it must be measured by its effects. A horse draws a cart and exerts a force which may be measured by pounds. A locomotive pulls or pushes a train of cars, and by placing a dynamometer between it and the train, the pounds of force which it exerts at any instant may be measured whether it moves the train or not. Similarly, whenever any effort is exerted, as a push through a rod or bar, or as a pull through a chain, rope, or rod, the effort can be measured by pounds. The force of gravity exerted upon a body at rest equals the weight of the body and is measured by pounds, but when the body is in motion, is the *force* still equal to the weight? To show that it is, we make use of the well-known formula,

$$F = M f$$

in which

F = the value of a single force (measured in pounds) acting upon a body perfectly free to move.

M = the mass of the body moved, and

f = the acceleration produced by the force F.

The value of M equals $W \div g$, where W is the weight of the body whose mass is M, and g the acceleration due to gravity at the place where W is determined. Hence, the formula becomes

$$F = W\frac{f}{g}$$

If we conceive a body whose weight is W to be pushed or pulled by a constant force equal to its weight, that is, by a force equal to W, we have

$$W = W\frac{f}{g};$$

or

$$f = g;$$

hence, the acceleration will equal that due to a body falling freely by the force of gravity.

To illustrate further, suppose that a body is placed upon a horizontal plane and is free to move without resistances, such as friction, adhesion or resistance of the air, and if the body be drawn by a string of which the constant tension equals the weight of the body, then will the motion horizontally be precisely the same as if the body fell vertically by the force of gravity. It is easy to hold the body so that when the tension of the string is the same as before, there will be no motion; but the effort in both cases will be the same, and this effort is measured directly by the tension of the string, which we know may be expressed by a certain number of *pounds*. I do not think it advisable to consider anything as force, or as the measure of force which cannot itself be measured by this unit. Momentum MV is measured by *foot-pounds*, and hence *generally* is not a measure of force. I say *generally*, for I will hereafter show that under *certain restrictions* it may be used as the measure of force. Similarly, work, living force, and energy, are measured by *foot-pounds*, and are not *generally* the proper measures of force.

Force manifests itself in a variety of ways. That which draws bodies towards each other, or repels them from each other, or holds the particles together forming solids, or which forces particles from each other, tending to disperse them, or which causes a particular arrangement of the particles as in fibrous and crystaline bodies, is force, whether it be called attraction, repulsion, cohesion, adhesion, polarity, electrical phenomenon, or chemical action.

A recent writer in Nature, reviewing a report of Professor Tait's lecture, says: "The whole controversy on the word force is as to the *method of measuring* a pressure or tension." Here *force* and *pressure* are considered the same. The natural mode of measuring *pressure* or *tension* is by pounds. He proceeds to say; "If we regard the time of action, the *effect* is represented by the momentum; and if the space through which exertion is made, the *effect* is represented by the work." These remarks are correct, but it should be observed that the *effects* are final effects; that is the momentum MV is the result of an effort for a time t, where t may be any finite time; and similarly in regard to work. He continues: "Either of these would measure 'force,' and there would be no inaccuracy if careful explanation were given as to the method used and the sense of the words." A simple illustration will show that neither of these can be a *general* measure of force. Suppose that a force of constant uniform intensity, produces a momentum of MV in a time t. Another force, beginning with less intensity, but gradually increasing with the time, might in the same time produce the same momentum. Certainly the momentum in the latter case, if a measure of the force at any instant of the action, will not be a measure of it at any other instant. Or the force may act very irregularly, and yet at the end of the time t, produce the same momentum. What in this case will be the measure of the force at any instant?

There is just one case in which momentum might be used to measure forces, and that is when the forces have a constant intensity during action. Such are called constant forces. Some writers have considered the formulas which are especially applicable to this case, as of a *general* character. For this case we have

$$\mathrm{F}\,t = \mathrm{M}\,\mathrm{V}.*$$

Similarly for another force, acting during the same time, we have

$$\mathrm{F}_1\,t = \mathrm{M}_1\,\mathrm{V}_1$$

Hence,

$$\mathrm{F} : \mathrm{F}_1 :: \mathrm{M}\,\mathrm{V} : \mathrm{M}_1\,\mathrm{V}_1$$

And by assuming one of the forces as a standard, or unit, for measuring all other forces, we have

$$\mathrm{F}_1 = \text{UNITY} = \mathrm{M}_1\,\mathrm{V}_1$$
$$\therefore\ \mathrm{F} = \mathrm{M}\,\mathrm{V}.$$

But forces generally are not constant, and to find a general expression for the pressure which moves a body in terms of the movement, we resort to the language of the Calculus. We consider that the force is measured by the momentum which it would produce in a unit of time, if it acted with the intensity that it had at the instant considered. The increased or decreased velocity which would be produced, is called *acceleration*,

* The general expression for any *law* of force is,

$$\int_o^t \mathrm{F}\,t = \mathrm{M}\,(\mathrm{V} - \mathrm{V}_o)$$

and hence the measure of the intensity of a variable force at any instant of its action when moving a perfectly free mass M, is the product of the mass by the acceleration, or, as we have previously expressed it,

$$F = M f.$$

This is a well-known expression, accepted by all writers upon Mechanics, and a careful study of it will remove much of the difficulty which seems to be involved in the case.

It will be observed here that F means a certain number of pounds, or their equivalent, and the right hand member may be reduced to the same thing. For we have

$$F = \frac{f}{g} W;$$

in which $\frac{f}{g}$ is the ratio of two accelerations, and hence, is an abstract number, by which, if W be multiplied, the result will be a certain number of pounds.

If in the expression

$$F = M f$$

we make M and f each unity, and consider F as constant, we have

1 lb. of force = 1 lb. of mass × 1 foot velocity;

the second member of which is the *unit*, proposed by the English writers for measuring force. But we see from the preceding principles that to be a *general* measure, the *unit* should be *that which would produce an acceleration of one foot per second in one pound of mass free to move.*

The second member of the equation is, as we have seen, an equivalent for the first member. It is only applicable to moving bodies, while the first member is general, being the direct measure of the pressure or tension, whether the body upon which the effect is made moves or remains at rest, and hence, we think, is the more natural, and certainly the more general measure of "force."

IRON AND STEEL THE FIRST THREE QUARTERS OF 1876.

From the London "Mining Journal."

In a recent number of the *London Mining Journal* was published the Custom House Returns of the commerce which took place for the first three quarters of this year in the three superior metals—tin, copper, and lead, assigning as our reason the importance of marking at each quarter of the year the progress made in the metal trade, in order that the present condition and prospects of mining may be more precisely ascertained, in the interest of that great branch of British industry of which the *Mining Journal* is the oldest and most efficient chronicle. Indeed, to do this is a necessity, for it is impossible to measure aright our mining prospects without watching with sustained vigilance the progress of the commerce in the products of our mines. An intelligent observer, if not thoroughly acquainted with the ways of mining brokers and agents, would be puzzled if he were to spend any day a few hours on the mining share-market, or call at the offices of Stock Exchange and mining brokers, and listen to their very various and even contradictory accounts of the "situation." We were informed this week by a gentleman largely interested in Welsh lead mines that business is reviving, that there is a rapidly increasing demand for shares in lead mines, more particularly Welsh. Another gentleman assured us that the stir in business proceeded from the success of the lead mines of the North of England. A third gentleman, an intelligent broker concerned in Welsh lead mines, assured us with doleful countenance that "there is no business doing; nothing whatever." Another said he "never knew things worse." His department is more especially in copper. A Cornish gentleman of forty years standing in mining experience declared that "tin mining in Cornwall was on the point of extinction," while another gentleman, who had equal opportunities of knowing, said, "Tin will look up, we need not now be much afraid of foreign

competition, and the prospects of lead mining are excellent." In fact, each man refers to the quality of his own individual business as the only test of the state and the prospects of mining in general. But when we give the statistics of the trade in metals and minerals at least every quarter, as furnished by authority, that "regulates the clock," and tells us what the real time is. This has been done for the third quarter and the three quarters of the year in connection with the three valuable metals above named. Our space did not permit us to comprehend all; let us now endeavor to point out the statistics of the iron trade as we have collected and collated them.

Although Great Britain is a great exporter of iron, and has been greater, our imports are also considerable, chiefly of Swedish iron for the manufacture of steel, the ores of that country being better adapted to the purpose than any other. Eventually this trade will be greatly lessened, some think abolished, because our new processes for the manufacture of steel enable us to adopt our own ores, but for some time to come iron is likely to give place to steel for various uses, more particularly rails, that the imports are not likely to diminish. During the last nine months ores were imported to the value of £681,000 (we shall confine ourselves to round numbers, giving the nearest round number approached). There has been a great increase over the first three quarters of 1875, when the value was £485,000 but the more active year, 1874, shows within the same period a value of £876,000. But last month shows that more iron was wanted (chiefly for making steel) than in the corresponding month of the two previous years; the figures were (moving backward), £87,642, £68,000, £77,000. Bar-iron was imported during this year up to the 7th of this month to the value of £750,000 against £950,000 last year in the same time, and £727,000 the year before that. It appears that foreign makers are not supplying us with bar-iron to the extent of last year, but the same activity in these imports prevailed as in those of ores; last month the value being more than in 1875 or 1874, and in proportion to the whole nine months increased about thirty-seven per cent.

Heavy complaints have been made that the German, Belgian, and even French, are beating us in iron manufactures in our own market. There are certainly some departments of iron manufactures in which the Germans excel us, both in skill and taste; but the area of coal is too small in Belgium for that country to maintain a permanent competition with us in any department of iron-making. The value of manufactured iron imported this year has been £1,047,-463—£30,000 less than last year, but over £70,000 more than at the same time the year before that. There is no material difference in those figures, but for the month there has been a marked diminution; the value for September was £111,145, against £155,000 in that month twelvemonths, and £149,000 in September two years. The value of imports for the month sustained the proportion of the nine months. As to quantity, the number of tons of ore greatly increased, and of bars twenty-five per cent., and there was over 160,000 cwts. more of manufactured iron imported. The imports of iron have been manifestly cheaper, an element, of course, to be considered in any estimate as to foreign competition. Our steel imports were all unwrought. For the nine months they were valued at £112,000, nearly thirty per cent. more than during the corresponding period last year, which was only a trifle less than in that period in 1874. But the month shows a signal falling off, the value having been only £9000. It was 250 per cent. more in September, 1875, and four times as much as in that month, 1874; and for the reasons given the diminution will, after some time, be more determined. The increase in quantities for the nine months shows falling prices upon the Continent; it was 7400 tons as compared with 5200 tons within the same time last year, and 4466 tons in that of 1874.

Perhaps it is proper here to notice our imports of pyrites. Those of iron, copper, and sulphur cannot be separated in the returns. The value of them all in the last three-quarters of a year has been very considerable, and ought not to be overlooked, as they constantly are in statistics of the metal trade. The amount has been £1,021,000 over £100,000 less than in the first three-quarters of last year, and a few thousand pounds less

than in those of the previous year. The decline on the month has been large, whether as compared with the whole nine months of this year or the corresponding months of previous years. There have been no material alterations in quantities, into the detail of which it is not necessary to enter. It must not be supposed by any reader who has not paid particular attention to the course of the metal trade that all the iron we import comes into direct competition with our own productions. Considerable quantities are exported, furnishing the metal or general merchant with a profit. Of course, there is no "re-export," as it is called, of ores; they are cumbersome cargoes, and not of an intrinsic value to sustain a commerce in them; besides, we only import what we require for manufacturing purposes. Neither do we reship pyrites of any kind. But of the bar-iron which we received we exported a value of £290,000. Last year it was £357,000, and the previous year rather less than this. The falling off in the "re-export" of iron does not appear to be due to any other causes than the general decline of trade here and elsewhere. Of iron manufactures other than bars imported we do not appear to have sold a single ounce. The whole came into competition with our own market when it made its way by superior artistic design and finish.

Of the unwrought steel bought here £37,000 worth was sent away again, an increase of £4000 upon the first three quarters of last year, and £3000 more than twice as much, in the corresponding months of 1874. For the month we exported nearly double the value of imported steel, as compared with the same time last year. Of the export of British iron and steel production we have little, if indeed anything, to say which would cheer the gloom which hangs over this department of our mining industry and commerce in metals. The falling off has been signal and terrible, and any light that hope sheds upon our path is rather in the prospect of renewed railway demand, and the certain change from iron rails to steel in every country. This will undoubtedly cause a renewed activity. Our great metallurgists and manufacturers are also beginning to take measures for raising the standard of artworkmen in iron and steel, so as more effectually to compete with our continental rivals, whether German, Belgian, or French. The value of our exports of iron and steel for the past three quarters of this year has been £15,690,000, nearly 4½ millions less than in the corresponding three quarters of last year, and more than eight millions less than in the corresponding quarters of 1874.

Some hopes have heen expressed lately in the columns of this Journal, and in the Press of the North of England and South Wales, that the export trade is improving a little; we are no croakers; but sad to say we see no decided sign of this. The value of the last month's exports was higher in proportion to the whole nine months. Were the whole three-quarters as good as the month the results would have been more favorable to the extent of about £2,000,000, for the exports of September were valued at £1,934,000. That, however, was less by £300,000 than September, 1875, and less by close upon £750,000 than in September, 1874. The decline has been very general, pervading nearly all branches. Unwrought steel fell from £838,800 in the longer period to £673,000; manufacturers of steel, or steel and iron combined from £615,000 to £575,000; pig-iron from £2,641,000 to £2,115,000; bar, angle, bolt, and rod from £2,048,000, to £1,459,000. In railroad iron of all sorts the decline has been very heavy. Last year in the first three-quarters the value was £4,500,000, this year not far from £1,750,000 less. For hoops, sheets, boiler, and armor-plates the fall was about £400,000, from £2,464,000 last year. Tin-plates declined still more, showing a diminution of £750,000 upon a value of less than £3,000,000 last year. Cast or wrought iron, and all other manufacture except ordnance, showed a recession from £3,368,000 to a trifle over £3,000,000. The only gain was in old iron exports for re-manufacture elsewhere, too small for notice.

It is well understood that iron enters largely into the composition of machinery. The value of steam-engines exported was over £2,000,000 the first three quarters of last year; this year, so far, only £1,470,000. The decline in other descriptions of machinery was even more serious; from less than £5,000,000 there

was a decline of nearly £900,000. Hardware and cutlery also presented a retrogression. Last year in the first three quarters the value was £3,200,000; this year, £2,650,000. In arms and ammunition the decline was not very heavy, but both years show a great falling off from the year before. The depression in the month of September is represented by the following figures—£2,667,000 in September, 1874; £2,236,000 in September, 1875; and £1,935,000 in September, 1876.

Unhappily the decline in quantities has been extraordinary as well as in values. Yet the cloud seems a little breaking up, and some streaks of light are breaking through. British energy, capital, perseverance, and trust in Providence must accomplish the rest.

THE PHOSPHATE SEWAGE COMPANY'S PROCESS.

By W. KEITH.

From "Journal of the Society of Arts."

THE Phosphate Sewage Process is based upon the use of specially prepared phosphates of alumina and lime with sewage. The action of the prepared phosphates upon the sewage may be familiarly described as a curdling or coagulation of the fæcal matter in the sewage, giving it thereby a greater tendency to separate itself from the general bulk of water with which it has been intermixed. The next step is the use of lime, and this draws from the sewage the soluble phosphates which have been added in the process, forming therewith what is known as precipitated phosphate. The formation of this precipitated phosphate not only has the effect of recovering from the sewage water the soluble phosphate it contained, but it also carries down with it the curdled or coagulated fæcal matter. The sewage having been thus prepared, a separation of the solid matter is readily accomplished by means of "precipitating tanks," constructed so as not to interfere with that quiet condition of the water which is necessary for the deposit of a light and flocculent precipitate.

By these successive steps the deodorization and defæcation of the sewage are accomplished, so that, whilst a flow of sewage enters at one end of the works, a stream of clear, bright effluent passes away at the other, leaving in the precipitating tanks a deposit of the solid matter which has been separated from the sewage. This solid matter is discharged into shallow beds, where it is allowed to dry, and it is either moulded into bricks and dried in the air, or simply turned over and the drying completed without further trouble, which is undoubtedly the cheapest course of procedure.

Manure obtained under the phosphate sewage process has many and great advantages over the ordinary sewage manures, which, from their inferior quality, are difficult of sale. As a matter of fact it has been found more economical to purify the sewage by the use of a better and more expensive class of material, which, when it has accomplished the duty of purifying the sewage, adds to the utility and market value of the manure made. The manure produced under this process enables it to be compared favorably with other manures. The average composition of the manure made from London sewage is about two and a half per cent. ammoniacal matter and twenty-two per cent. precipitated phosphates, and, consequently, it is a really valuable manure.

The sewage of Hertford is one of that class which offers especial difficulties, consequent upon its having to be discharged into the Lea, which is largely drawn upon as a water supply, and is for this reason very jealously guarded. The sewage of this town has been continuously treated by this process for about eighteen months, and it has so far complied with the stringent conditions of producing a thoroughly good effluent water, that the Corporation have given an official certificate testifying to the

satisfactory character of the effluent water discharged.

Professor Wrightson, in his report to the Cirencester Chamber of Agriculture upon one of the most complete series of field experiments of modern times, says of this manure:

"It is advertised at £4 per ton, delivered in railway trucks, and I can speak most approvingly of the fine, dry condition in which it is sent out, in strong bags of 1 cwt. each. Last year I spoke of its uniform action over many of the farms upon which it was tried. It did not produce so great an increase as superphosphate, but then it was sold at a lower price. Reducing its effects to a money standard, I found last season that it produced its increase over unmanured plots, taking the average of the entire series, at 3s. 2½d. per ton, whereas superphosphate, valued at 6s. per cwt. produced its increase at 3s. per ton. The results of 1875 are certainly favorable to this sewage product, as may be readily seen by consulting the table showing the increase per acre of the fertilizers used over the average unmanured plots. It rivals superphosphate in several cases, especially at Stratton, where it gave a distinctly better result. In other cases the popular manure, superphosphate, is run very hard by it. Twelve shillings per acre is some vantage ground when compared with the 18s. per acre at which I have valued the superphosphate, and, applying the rule for finding the profit from any fertilizer, I find strong evidence, now extending over two seasons, of the usefulness of this substance."

PRESERVATION OF TIMBER WITH SALTS OF COPPER.*

By M. ROTTIER.

From "Engineering."

1. Wood impregnated with copper will not last underground for an indefinite time. However carefully prepared it decays after a longer or shorter interval. This fact admits of ready explanation.

Under the influence of certain agencies wood so prepared gradually parts with the small quantity of copper fixed in its tissues, to the pressure of which its antiseptic powers were due. So long as the wood contains a certain proportion of copper, it resists decay; when the copper is no longer there it is in pretty much the same condition as unprepared wood, and speedily decomposes. This is clearly shown by the following experiment:

Some thin slips of soft poplar-wood were carefully dried and afterwards impregnated with a solution of pure copper sulphate, containing 1.5 gramme of crystallized sulphate of copper per 100 parts of water. It was not found necessary to resort to pressure, as the wood being very thin, mere immersion sufficed for its thorough impregnation with the antiseptic fluid. The strips were washed several times in plenty of water, and dried. Some were then set apart for analysis, and others buried in a box filled with ordinary garden mould kept continually moist by repeated waterings. The annexed Table shows the results:

	Length of Time the Strips were interred.	Proportion of Crystallized Sulphate of Copper found in them.	Remarks.
	days.	grams.	
1 gramme of wood prepared & dried	0	0.00410	
1 gramme of wood prepared & dried	68	0.00250	Wood still perfectly sound.
1 gramme of wood prepared & dried	117	0.00220	Strips showing a few black spots.
1 gramme of wood prepared & dried	179	0.00170	Wood almost entirelydecayed.

* Communicated to the Academie des Sciences de Belgique.

Here we see, as plainly as it can well be shown, that the preservation of the wood was due to the presence of the cupreous sulphate; by degrees, as it parted with this metallic salt, it decayed. Now let us consider the causes of removal of the copper. They are three: 1. The presence of iron. 2. The presence of certain saline solutions. 3. The presence of carbonic acid.

To a Belgian engineer, M. Van der Sweep, belongs the credit of having first called attention, some years ago, to the action of metallic iron on timber prepared with salts of copper.

The researches of Kuhlmann, Themard, and Hervé-Mangon on this point, appear sufficiently conclusive to render further experiments unnecessary. But it was thought desirable to ascertain the point at which the presence of iron in cupreous solution becomes detrimental to the antiseptic properties of wood.

A certain number of thin slips of wood of the same size were prepared with solutions of copper sulphate containing different proportions of sulphate of iron, The length of time the wood remained sound in each case was noted. The annexed Table shows the results:

Number of Experiment.	Weight of Slips.	Composition of Solutions employed.			Slips completely destroyed at the end of:
		$Cu\,So_4\,5\,H_2\,O.$	$Fe\,So_4\,7\,H_2\,O.$	$H_2O.$	
	grams	grams.	grams.	grams.	days.
1	0.25	0.00	1.50	100.00	56
2	0.25	0.50	1.00	100.00	83
3	0.22	1.00	0.50	100.00	97
4	0.22	1.20	0.30	100.00	100
5	0.22	1.30	0.20	100.00	103
6	0.19	1.40	0.10	100.00	103
7	0 19	1.45	0 05	100.00	108
8	0.18	1.48	0.02	100.00	109
9	0.20	1.49	0.01	100.00	109
10	0.23	1.495	0.005	100.00	110
11	0.20	1.50	0.00	100.00	109
12	0.25	1.46	0.04	100.00	100
13	0.24	1.48	0.02	100.00	100
14	0.26	Strip not prepared.			34

In all these experiments, the wood was in every case entirely rotted, so that it could not be drawn out of the soil without crumbling. Very exact analysis was, therefore, impracticable, and but little importance should be attached to minute differences in the results. An examination of the last Table shows:

1st. That sulphate of iron has a certain antiseptic power, which is, however, much inferior to that of sulphate of copper.

2d. That samples of wood prepared with different solutions containing the sulphate of iron and copper together last about the same time, unless the sulphate of iron is present in very large quantity.

3d. That there is no reason to give the preference in wood-preserving to chemically pure copper sulphate over the ordinary sulphate of copper of commerce.

M. Boucherie has advanced a contrary opinion. He asserts that cupreous sulphate containing five or six per cent. of sulphate of iron should be rejected altogether, and that in wood-preserving only copper sulphate, which has been suitably purified, should be employed.

Without entering upon this question, it may be well to recall the experiments of Payem, on the wood of an ancient wheel found, some years ago, in the Sao Domingo copper mine in Portugal. This wheel was in a perfect state of preservation after having lain for fourteen centuries in water impregnated with the sulphate of copper and iron, and containing a notable proportion of the subsulphate of these metals.

Certain salts have an injurious action on wood impregnated with sulphur of copper. When wood so prepared, after washing in distilled water, is plunged in a solution of the chloride or carbonate of soda or of carbonate of potash, it will be found after the lapse of a certain time, that these solutions contain a notable percentage of copper. On the other hand, if preparation of copper in the wood be determined before and after an immersion of varying duration, it will be found to decrease steadily in proportion to the length of the immersion. This explains the failure of all attempts to protect timber against the action of sea-water with sulphate of copper. The salts in the sea-water enable it rapidly to dissolve out the copper from the woody fibre. So long as the copper is present in the timber, the latter is spared by the marine mollusca; when the greater portion of it is washed out, the wood

speedily succumbs. This was proved by exposing a piece of beech-wood thus prepared to the action of sea-water for a given time. One part of the wood was untouched; the other was deeply eaten away by the borer. A sample of the wood weighing 2.5 grammes, from the untouched part was found to contain 0.01140 gramme of sulphate of copper; a sample of equal weight from the portion attacked contained 0.00015 gramme only. To a similar cause most likely is due the rapid decay of sleepers prepared with sulphate of copper, when laid in tunnels in certain soils, in those of a calcareous nature more especially. The water filtering through these soils very possibly becomes charged with certain salts (bi-carbonate of lime, &c.), which like sea-salt, carbonate of soda, and others, have the property of carrying off the copper from wood prepared therewith.

Solutions containing carbonic acid act in the same way. About three grammes weight of wood prepared with sulphate of copper, was carefully washed, and exposed for seven days to the action of frequently renewed solutions of carbonic acid (*i. e.* aërated water). Each time the water was removed it was tested for copper. The total amount of copper thus extracted in the seven days was 0.0028 gramme of sulphate. Under similar conditions pure water has no effect. Maxime Paulet, in his last work describes an experiment in point:

"Take," he says, "some wood sawdust impregnated with copper sulphate, and wash it repeatedly until the presence of copper in the latter can no longer be detected with ferrocyanide of potassium. Throw this sawdust, out of which all the copper has apparently been extracted, into ordinary aërated water, that is to say water highly charged with carbonic acid, and leave it there for awhile. The water is found to show traces of copper. How has this come to pass? We may be permitted to surmise that the oxide of copper has become dissolved under the influence of the carbonic acid and so extracted from the wood. The experiment requires to be repeated; but if the foregoing view should be confirmed, the practical importance of the deduction is sufficiently obvious."

Experiments were next made to ascertain whether *pure* water also exerts a solvent action on the cupreous combinations contained in wood prepared with copper sulphate.

1st. In an open vessel filled with distilled water were placed some slips of wood prepared with copper and carefully washed. The mouth of the vessel was covered with a pane of glass to prevent evaporation, and left exposed to the light for a considerable length of time. Portions of each strip, about one-fifth of the superficial area of each, were cut off before immersion to serve as standards. Similar test-pieces were cut off from the slips at the end of 7, 13, and 19 months' immersion.

	Grammes.
The average proportion of copper in 1 gramme of the prepared wood before immersion was.....	0.0073
The average proportion of copper in 1 gramme of the prepared wood after 7 months' immersion in distilled water.....	0.0054
The average proportion of copper in 1 gramme of the prepared wood after 13 months' immersion in distilled water.....	0.0060
The average proportion of copper in 1 gramme of the prepared wood after 19 months' immersion in distilled water.....	0.0054

The action of the water was thus clearly manifest; but then the question arises, was the solvent power exerted by the water itself, or by a small proportion of carbonic acid which may have been present therein? Too much stress must not be laid on the result of a single experiment; but the latter supposition would account for the close equality of the copper in the last three tests.

2. Distilled water was boiled in a glass receiver so as to expel the gas. Slips of prepared wood, similar to those used in the previous experiment, were immersed in the water, which was again boiled, and the neck of the receiver sealed with the blowpipe. After 200 days it was opened. This water contained 0.0002 gramme of copper.

Even in this case, however, it must not be too hastily concluded that the solvent action really was exerted by the water. Even after long boiling, water is wonderfully retentive of small quantities of carbonic acid. And, again, if the wood was not thoroughly and uniformly saturated with the copper, the

smallest fragment that had escaped impregnation might have supplied a certain volume of carbonic acid to the water. In any case, the foregoing experiments prove that the action in such cases is extremely slow.

As timber prepared with copper is liable to decay when the proportion of the latter contained in it becomes very small, it appears probable that its duration might be prolonged by fixing a larger quantity of copper in the ligneous tissue. Let us now see whether experiment confirms this supposition.

The ordinary method of preparing timber does not permit of the solution of the question; wood plunged in a solution of copper sulphate takes up a pretty nearly constant quantity of the metal; and that quantity is very small. Special processes are requisite to introduce larger quantities of the metal into the tissues. The following have given satisfactory results.

1st. *Acetate of Copper.*—The tendency to fix themselves in ligneous fibre is displayed in different degrees by different copper salts. The acetate is specially noticeable in this respect. Slips of wood impregnated with acetate of copper were found to contain 0.0104 to 0.0170 gramme of copper per gramme of wood; whilst those prepared with equal weights of sulphate contained only 0.006 to 0.007 gramme of copper per gramme of wood.

2d. *Use of Organic Substances.*—Some organic substances act in respect of the salts of copper like mordants on dye-stuffs—they assist the absorption and fixation of the copper by the ligneous fibre. The two organic substances, which were found to give the most remarkable results, were indigo and catechu.

3d. *Heating of the Wood.*—When slips of wood prepared with a solution of copper (acetate or sulphate, &c), on their withdrawal from the bath, are exposed to a high temperature, they appear to assimilate and retain in an insoluble form, a somewhat larger proportion of copper than it would be possible to introduce in the ordinary way. The following Table gives the results of some experiments under this head :

	Temperature to which heated.	Copper in one Gramme of Wood.
	deg. C.	grms.
Strips of wood prepared with copper sulphate, and heated to.....	65	0.0075
Strips of wood prepared with copper sulphate, and heated to.....	100	0.0090
Strips of wood prepared with copper sulphate, and heated to.....	125	0.0114
Strips of wood prepared with acetate, and heated to...	100	0.0231
Strips of wood prepared with acetate, and heated to....	130	0.0240
Strips of wood prepared in the ordinary way.....	..	0.0073

a. Indigo.—A slip of wood was dyed blue with indigo, and then prepared with a solution of copper sulphate in the ordinary way. It was found to contain 0.0093 gramme of copper per gramme of wood, which is rather above the average of ordinary wood prepared in the same way. The experiment was repeated with indigo-dyed and white calicoes. The blue retained after washing 0.00409 gramme of copper per gramme of material, whilst the white contained 0.00195 gramme only. A blue calico with a white pattern was treated with copper sulphate in the same way, and the white portions cut out. The proportion of copper fixed by the latter was found 0.00026 gramme only; the blue ground fixed 0.0130 gramme per gramme of the stuff.

b. Catechu.—If a decoction of catechu be mixed with a solution of acetate or sulphate of copper, a liquor is obtained which allows of the fixation of a very considerable quantity of copper in wood. Strips of wood so prepared were found to contain 0.0145 gramme to 0.0460 gramme of copper per gramme of wood. Contrary to expectation, this method proves of little practical value. Catechu requires the presence of oxygen to produce the required effect. Thin strips of wood, having a surface large in proportion to their thickness, may thus be made to absorb considerable quantities of copper, but in timbers of any moderate

scantling, the effect is merely superficial, and the proportion of copper fixed relatively small.

c. Ammoniacal Copper Salts.—The use of the ammoniated salts of copper allows of the introduction of large quantities of copper in woody tissue. Numerous experiments showed that wood so prepared contained from 0.0166 gramme to 0.0730 gramme of copper per gramme of wood.

It appears, therefore, that there are various ways of impregnating wood with copper in excess of the ordinary proportion. It remains to be seen whether the excess of copper gives a notable increase of durability. To decide this question seven strips of wood were buried in the ground side by side: 1. A strip unprepared, A. 2. A strip prepared with sulphate of copper, B. 3. A strip prepared with acetate, C. 4. A strip prepared with catechu, D. 5. A strip prepared with sulphate and afterwards heated, E. 6. A strip prepared with acetate and heated, F. 7. A strip prepared with cuprammonium sulphate. The results are given below:

(*See Table on following column.*)

	1 Gramme of Wood contained of Cu So_4 5 H_2 O.	Wood completly rotted after.
	grammes.	days.
A. Unprepared wood.....	0.00002	30
B. Wood prepared with copper sulphate in the ordinary way.....	0.00730	67
C. Wood prepared with acetate of copper	0.01000	95
D. Wood prepared with sulphate of copper and catechu	0.01300	120
E. Wood prepared with sulphate of copper and heated afterwards....	0.01000	80
F. Wood prepared with acetate of copper and heated afterwards.....	0.02300	160
G. Wood prepared with ammoniacal copper sulphate.....	0.01660	130

These results have been confirmed by repeated experiments, in some of which the prepared slips of wood were found as fresh and sound after an interment of 200 days, as when first consigned to the ground.

Of the several methods above described, one only, the employment of ammoniacal copper salts, appears of any practical utility. Acetate of copper and indigo are each of them too expensive; catechu is too restricted in its action. On the other hand, the ammoniated salts of copper are adapted for general use, and are, comparatively speaking, cheap, and the slightly increased outlay necessitated by their adoption would be more than compensated by the assurance of greater durability in the timber so prepared.

PROTECTION OF BUILDINGS FROM LIGHTNING.*

From "The Architect."

THE author stated that those who had given directions for the construction of lightning-conductors had paid great attention to the upper and lower extremities of the conductor. They recommended that the upper extremity of the conductor should extend somewhat above the highest part of the building to be protected; that it should terminate in a sharp point; and that the lower extremity should be carried as far as possible into the conducting strata of the ground, so as to "make" what telegraph engineers called a "good earth." The effect was to tap, or, as it were, to gather the charge by facilitating the discharge between the atmospheric accumulation and the earth. That would cause a greater number of discharges than would have otherwise occurred; but each of them would be smaller than those which would have occurred without a conductor. It appeared to him that these arrangements were calculated rather for the benefit of the surrounding country, and for the benefit of clouds laboring under an accumulation

* Abstract of Prof. Clerk Maxwell's paper before the British Association.

of electricity, than for the protection of the building on which the conductor was erected.

What the people really wished was to prevent the possibility of an electric discharge taking place within a certain region—say the inside of a gunpowder manufactory. If this were clearly laid down as the object to be aimed at, the method of securing it was equally clear. An electric discharge could not occur between two bodies unless the difference of their potentials was sufficiently great compared with the distance between them. If, therefore, they could get the potentials of all bodies within a certain region equal, or nearly equal, no discharge could take place between them. They might secure this by connecting all these bodies by means of good conductors, such as copper-wire ropes, but it was not necessary to do so, for it might be shown by experiment that if every part of the surface surrounding a certain region was at the same potential, every part within that region must be at the same potential, provided always that no charged body were placed within the region. It would therefore be sufficient to surround the powder mill with conducting material—to sheathe its roof, walls, and ground floor with thick sheet copper, and then no electrical effect would occur within it on account of any thunderstorm outside. There would be no need of any earth connection. They might even place a layer of asphalt between the copper floor and the ground so as to insulate the building. If the mill were struck it would remain charged for some time, and a person standing on the ground outside or touching the wall might receive a shock, but no electrical effect would be perceived inside, even by the most delicate electrometer. A sheathing of copper was by no means necessary in order to prevent any electrical effect taking place. Supposing a building were struck by lightning, it was quite sufficient to enclose it with a network of a good conducting substance. Then, again, if copper wire were carried round the foundations of a house, up the edges of the corners and gables, and along the roofs, this would probably by a sufficient protection for the building against any thunderstorm in this climate. The copper wires might be built into the walls to prevent theft, and they should be connected with any outside metal, such as lead or zinc on the roof, and with the rain-water pipes. In the case of a powder mill, it might be advisable to make the network closer, carrying one or two wires over the roof and down the walls to the wire at the foundation. If there were water or gas pipes entering the building from without, these must be connected with the system of conducting wires, but if there were no such metallic connections with distant points, it was not necessary to take any pains to allow the escape of electricity into the air; still less was it advisable to erect a tall conductor with a sharp point in order to relieve thunder clouds of their charge. It was hardly necessary to add that it was not advisable during a thunderstorm to stand on the roof of a house so protected, or to stand on the ground outside, or to lean against the wall.

ON GAUGING OF STREAMS.

By DAVID M. GREENE, C. E.

Transactions of the American Society of Civil Engineers.

In the examination of questions frequently arising among neighboring mill owners using the water power of our country streams, it almost always happens that the engineer is called upon to form an opinion—as to the adaptability of the machinery used to the available power of the stream, and as to the "reasonable use" of such power.

It is assumed that so much machinery may be employed, at any point upon any stream, as can be effectually and fully operated by the water flowing therein at its "ordinary stage." What,

then, is the ordinary stage of a stream? We answer, that it is the minimum flow occurring during from eight to nine months of the year, excluding the three or four months of low water usually occurring during the late summer, early autumn and in mid-winter. In other words, machinery properly adapted to the flow of water in the stream upon which it is located, may run without interruption from a defective supply of water, during eight to nine months in each year.

The extent of the interruptions which are to be expected during the remaining three or four months, will, of course, depend upon the extent to which extreme low water falls below the ordinary stage, and upon the duration of the extreme low stage.

It is assumed that such an adaptation of machinery is a fair compromise between the condition of an amount of machinery adapted to the maximum flow, which would be subject to constant interruption throughout the entire year, and that of machinery adapted to the minimum flow, which, while able to run uninterruptedly, would involve a constant and very large waste of power, except during the generally brief period of extreme low water.

The charge of "unreasonable use" is usually made when, during low water, mill owners draw more than is naturally flowing in the stream, until their ponds are exhausted, or their heads reduced to such an extent as to necessitate the stoppage of their works, and then shut their gates for the purpose of filling their ponds; thus entirely suppressing, for a longer or shorter time, the flow of water, and of course, interfering with the operations of the machinery below.

Again the charge of "unreasonable use" is sometimes made by the manufacturers whose business requires them to run their machinery night and day, and who, therefore, require a constant and uniform flow of water; when their up-stream neighbors, running their machinery during the day only, draw down the water during the day, and at night shut down their gates in order to accumulate a supply of water for the following day, thus sending down an unusual and unnatural quantity by day, and almost entirely suppressing the flow at night.

It is not, however, my purpose to discuss the various and complicated questions growing out of the use of water power, but rather to indicate the means I employed in an important case, to determine the minimum flow of a stream, and its relation to the use by a cotton factory, as a means of ascertaining approximately, whether the quantity of water used by the factory was or was not greater than the ordinary flow of the stream.

In the case referred to, an improved Fourneyron turbine about eight feet in diameter was used, under a head of forty feet. This turbine was so carefully constructed, that the quantity of water used upon it could be determined very accurately, and the dam was tight.

The observations were made during the period of extreme low water, in summer, and in the following manner: *First* the pond being full to the crest of the dam—no water flowing over—the factory was started up and run to its fullest capacity, until the pond had been drawn down about two and a half feet. *Second*, the gate was then closed tightly, and the pond allowed to fill to the point at which it stood when the machinery was started. *Third*, the times required to draw down the pond and to fill it again were carefully noted.

These operations were repeated several times—drawing the pond down various distances, ranging from four inches to two and a half feet. While drawing down the pond, in each case, a determinate quantity of water was used by the turbine, which was equal to an indeterminate quantity stored in the pond, plus the indeterminate quantity flowing in the stream at the same time. While the pond was being raised to its former level, in each case, the above indeterminate quantity of water was being stored therein from the normal minimum flow of the stream.

In order to express the relations analytically, to eliminate the volume of water stored in and drawn from the pond during each experiment, to determine the relation between the volume flowing in the stream and the quantity used by the turbine, and to ultimately deter-

mine the minimum flow of the stream, we proceed as follows :

Let Q, equal flow of the stream, and Q', the flow through the turbine, in cubic feet per minute ; t' the time required to draw down the pond ; and t for pond to fill to original level, in minutes ; and V, the volume stored in and drawn from pond, during experiment, exclusive of flow of stream.

Then $V = Qt$, and the quantity used by the wheel, while drawing down the pond, $V + Qt = Qt + Qt' = Q't'$; when

$$\frac{Q}{Q'} = \frac{t'}{t+t'}; \text{ and } Q = Q'\left(\frac{t'}{t+t'}\right)$$

Several experiments were made, in which the value of $\frac{Q}{Q'}$ ranged from 0.65 to 0.69; showing that, at extreme low water, the stream furnished about 66 per cent. of the quantity of water required to run the factory continuously, at its full capacity; or considerable more than would be required to run at full capacity during ten hours of each day, provided the flow could be controlled during the night.

Similar experiments, made at the ordinary stage of the stream—or at any stage—when the flow is less than the quantity used upon the wheel, would furnish the relations between Q and Q' at those stages.

This method,—original with the writer—is believed to be far more satisfactory and to furnish much more reliable results, in cases similar to that herein described, than the rude and uncertain methods in which sections and velocities of the stream are taken, or where the discharge over dams is estimated.

NOTE ON THE MOST ECONOMICAL DEPTH OF STRAIGHT GIRDERS AND TRUSSES.

By EMIL ADLER, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

It is a very unprofitable labor to deduce strictly mathematical rules for the selection of the most economical depth of girders and trusses, inasmuch as such rules would have very little practical value from various reasons, which I will briefly recite.

1/ Such rules or formulae would have to contain so many variable quantities, that their application would take more time, than any engineer, accustomed to such work, would occupy in making and eventually remaking a complete estimate. These variable quantities would have to be : the live load, the dead load, the panel length and the unit strains. These latter are different for tensile and compressive members, and again different for compressive members according to the proportion of the length to the least diameter of gyration, both tensile and compressive unit strains again varying with the different specifications.

2/ It would be impossible in such rules if they had to be in any way general and applicable to all spans, all kinds of details and every system, to introduce the least sections, which practically can be used, especially in compressive members, neither could all the many small and minor quantities be introduced, which remain constant with each special mode of constructing the details and hence with each building firm; but on the other side vary very much with different details and hence with every different building firm.

3/ The girders proper form after all only a part of the whole amount of material, and the floor system forms another essential part, and hence the panel length has to be selected; not so, that the material in the girders proper becomes a minimum; but so, that the combined material of trusses proper and floor system becomes a minimum. To introduce this into the rules in a general manner would require such a complication, that any engineer would become discouraged, and it has so far never been undertaken;

hence the panel length has always to be selected beforehand, and to this selection experience is the best guide.

Only a few reasons why such formulae would have little practical value have been briefly summed up, as I feel confident, that any engineer, who has ever made an estimate for a bridge, would never think of using such formulae. Nevertheless the deduction of such formulae is not altogether useless as it might develop, and certainly has developed relations between the lengths of different members, or, what is the same, certain angles for the inclined members, which in certain special cases lead to economy.

There exists, however, a simple relation, common to all systems of straight trusses, that is: trusses with two parallel horizontal chords; a relation between the quantity of material in the chords and in the Web system which must be fulfilled to insure the most economical depth. We will find that this relation is independent of the load, the unit strains and the least practically possible sections, and hence holds good for any special mode of construction. This relation has, as we shall see, too, the advantage of an astonishing simplicity, which I believe will be a recommendation to practical engineers.

Before undertaking the deduction of this relation, it will not be out of the way to point out distinctly what we are aiming at. Our aim is not from reasons above mentioned, a priori to determine the most economical depth, but after a strain sheet and bill of quantities have been made, after the system, the panel length and the depth have been chosen; to determine whether the chosen depth is the most economical or not and on which side has been erred. The writer believes, that the relation at which we shall arrive has in one special case been known from experience to many bridge engineers, but he is not aware that any proof of this relation has ever been given, nor that any allusion to its existence has ever been made.

We shall now at once enter upon our subject and, after first calling into mind the general criterion that any function becomes a minimum or a maximum, separately treat of plate girders and trusses.

The criterion, that any function $f.(h)$ of a variable h for a certain value of h becomes a minimum or a maximum is, that for a small positive or negative increment $\triangle h$ to the variable, the equation:

$$\lim. \frac{f.(h+\triangle h - f.(h)}{\triangle h} = \frac{d.f(h)}{d.h} = 0$$

is fulfilled, or in plain language: a function $f'(h)$ of a variable h becomes a minimum or a maximum for such values of h, that a small increase or decrease of this value does not perceptibly change the function.

PLATE GIRDERS.

a. Plate girders with constant section. —The web thickness of plate girders can easily be calculated from the maximum shearing strain in the neutral axis; but this calculation nearly always gives results practically too small, that is: such thickness of Web plate as could not be obtained and would require an impracticably close spacing of rivets; hence the thickness of the Web plate has to be assumed and is assumed dependent on the height; but the same for any height, which in each particular case can be chosen.

Let M be the largest moment of exterior forces, which determines the section, and S the maximum unit strain, then:

$$\frac{M}{S} = R = \text{Moment of Resistance.}$$

If we now have a plate girder, with the section of one flange equal F and consider the small part the web gives to R as equivalent to the loss in the rivet holes, as is generally the case and call t the thickness of the Web plate; then we have:

$$R = F.h \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Now the total area of the section is: $h.t + 2F$, and this quantity has to be a minimum being proportional to the weight, hence:

$$h.t + 2F = \text{function } h = f.(h) = \text{Minimum} \quad (2)$$

if we substitute F from (1) in (2) we get:

$$h.t + \frac{2R}{h} = f(h) = \text{Minimum} \quad . \quad (3)$$

here R is a known value $= \frac{M}{S}$, and we have:

$$\frac{d.f(h)}{d.h} = t - \frac{2R}{h^2} = 0 \quad . \quad . \quad . \quad . \quad (4)$$

if we here again substitute R from (1) we get:

$$t - \frac{2F}{h} = 0 \text{ or } h.t = 2F \quad . \quad . \quad (5)$$

this equation (5) says:

We have the most economical depth of girder, when the weight of the Web is equal to the weight of the flanges; for $h\,t$ is the section of the web and $2\,F$ is the section of the two flanges, and with constant section these quantities are proportional to the weights.

Although the nature of this problem clearly shows, that for finite values of h the function has no maximum, we might still for this case prove that we really have a minimum and not a maximum; this is proved by showing, that the second differential coefficient is positive. We have from (4)

$$\frac{d^2.f(h)}{dh^2} = + \frac{4R}{h^3}$$

and as R is positive, and h, too, always positive, our function cannot for finite values of h have a maximum.

b. Plate girders with variable flange section.—Here the same remarks about the thickness of the Web plate as in the former case hold good.

If we now consider a plate girder of the height h and thickness of the Web t, and call the quantity or volume of material in the two flanges M_fl, and suppose the height to be altered with the small quantity $\triangle h$; then the strains in the flanges, and hence the section will be altered in the proportion $\frac{h}{h+\triangle h}$, and we have, l being the length of the girder, the total quantity of material:

$$f'(h+\triangle h) = M_fl \frac{h}{h+\triangle h} + (h+\triangle h)t.l \quad (1')$$

$$f(h) = M_fl + h.t.l \quad . \quad . \quad (2')$$

by subtracting (2′) from (1′), and dividing by $\triangle h$, we get:

$$\frac{f.(h+\triangle h) - f(h)}{\triangle h} = -M_fl \frac{1}{h+\triangle h} + t.l \quad (3')$$

$$\lim. \frac{f.(h+\triangle h) - f.(h)}{\triangle h} = -\frac{M_fl}{h} + t.l = 0 \quad (4')$$

or: $M_fl = h.t.l \quad (5')$; this says: *for the most economical depth the quantity of material in the flanges must be equal to that in the Web*; as $h\,t\,l$ is the volume of the material in the web.

We have here exactly the same relation as we had for plate girders with constant section, and in fact the same deduction as we have applied here holds good for the former case, which was only treated separately on account of the greater practical interest attached to it.

It needs no proof, that in case the weight of the Web material is greater than the weight of the flange material in these two cases, the height, that has been chosen is too great and vice versa. Practical engineers will know in which cases this astonishingly simple relation is of any value, as in many cases, perhaps the most frequent, the height, which can be chosen, lies between very narrow limits, and the most economical depth lies without these limits. In such cases our relation is of course of no direct use; but the knowledge of its existence might still be a valuable guide.

TRUSSES.

We now come to a series of cases, where more practical value will be attached to a similar simple relation as the height is not generally limited here. I am confident that most bridge engineers will be agreeably surprised to find here an analogous relation, which is quite as simple as the foregoing.

In the following deduction some assumptions must naturally be more or less concealed; but their justification will be more easily understood when they are pointed out after the deduction has been made, and we shall then, with the limits of the correctness of our assumptions, get the limits for the application of our relation.

For the deduction I shall, as an illustration, use a rectangular truss with single intersection and vertical end post, merely for the reason, that I have to use some illustration; but a way of deduction and a notation shall be used, which will plainly show the generality of the relation to any body acquainted with the simple calculation of strains in straight trusses.

The variable quantity of material in a truss, when the necessary data for calculation, as span, live load per foot, unit

strains, etc., are given, and the panel length, general design and system of details have been chosen, is a function of the only remaining independent variable, namely, the depth h.

If we now call M the whole amount of variable material we have:

$$M = f.(h) = \text{Minimum.}$$

The nature of this function can be determined thereotically, but not practically, as has been shown at the commencement of this paper; but without knowing the nature of this function we can find a relation, which must exist in order to make the function a minimum.

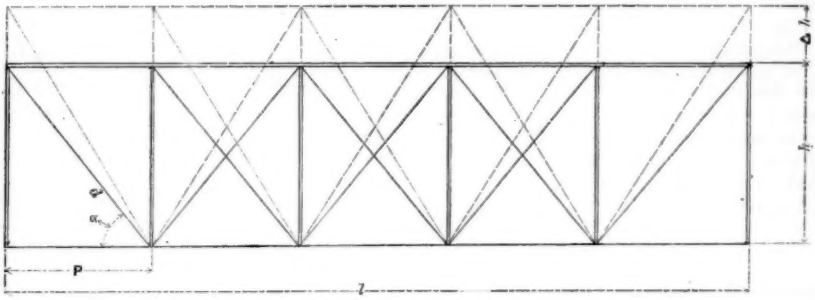
If we have any straight truss of span l, panel length p and height or depth h, we have a certain amount of material in the chords, in the vertical members and in the inclined members or diagonals.

We shall call these quantities:

M_c = Material in chords.

M_v = Material in vertical members.

M_i = Material in inclined members.



If we now alter the height with the small quantity Δh, all the above quantities will change and we shall see separately for each of them in what proportions they are changed.

1/ The strains in the vertical members have not changed and hence their sections have remained the same, and as their lengths have been altered in the proportion $\frac{h+\Delta h}{h}$; the quantity of material in these vertical members has altered in the same proportion, and is after the change of height

$$M_v \frac{h+\Delta h}{h} = M_v + M_v \frac{\Delta h}{h}$$

2/ The strains in the horizontal chord members, and consequently their sections, have been altered in the proportion $\frac{h}{h+\Delta h}$, and as the length of these members has been unchanged the quantity of material has been altered in the same proportion as the sections and is therefore after the change:

$$M_c \frac{h}{h+\Delta h} = M_c - M_c \frac{\Delta h}{h+\Delta h}$$

3/ The inclined members have changed their length, as well as their sections, and therefore the material has changed in proportion of the product of proportions of changes in length and changes in section.

If we call the length of a diagonal d, before the change, and its inclination to the horizontal chord α, then its length will be $d + \Delta h \sin \alpha$ when the height is changed with the small amount Δh and the proportional change is

$$\frac{d+\Delta h \sin. \alpha}{d}$$

The strains have altered in the proportion

$$\frac{d+\Delta h \sin. \alpha}{h+\Delta h} \cdot \frac{h}{d}$$

and the quantity of material has changed in the proportion of the product of these two proportions and is therefore after the change in height:

$$M_i \left(\frac{d+\Delta h \sin.\alpha}{\alpha}\right)^2 \cdot \frac{h}{h+\Delta h} = M_i + M_i \left(\frac{h \Delta h^2 \sin.^2\alpha + 2\, h.d \Delta h \sin.\alpha - d^2 \Delta h}{d^2 h + d^2 \Delta h}\right)$$

We have now:

$$f(h+\triangle h)=M_v+M_v\frac{\triangle h}{h}+M_c-$$

$$M_c\frac{\triangle h}{h+\triangle h}+M_i+$$

$$M_i\left(\frac{h\triangle h^2\sin.^2\propto+2hd\triangle h\sin.\propto-d^2\triangle h}{d^2.h+d^2\triangle h}\right)$$

$$f(h)=M_v+M_c+M_i$$

Subtracting and dividing by $\triangle h$, we get:

$$\frac{f(h+\triangle h)-f(h)}{\triangle h}=M_v\frac{1}{h}-M_c\frac{1}{h+\triangle h}$$

$$+M_i\left(\frac{h\triangle h^2\sin.^2\propto+2h.d.\sin.\propto-d^2}{d^2.h+d^2\triangle h}\right)$$

$$\text{or lim.}\frac{f(h+\triangle h)-f(h)}{\triangle h}=\frac{M_v}{h}-\frac{M_c}{h}$$

$$+M_i\frac{2h\sin.\propto-d}{d}$$

Now for a minimum, this must be equal to zero, and multiplying by h and considering that sin. $\propto\frac{h}{d}$, we get:

$$M_v-M_c+M_i\frac{2h^2-d^2}{d^2}=0$$

or $M_v-M_c+M_i(\sin.^2\propto-1)=0$, or

$$M_v+M_i\cos.(180^\circ-2\propto)=M_c \quad (I)$$

that is in ordinary language.

For the most economical depth, the material in the two chords together must be equal to the material in the vertical members, plus the material in the inclined members, the latter multiplied by cosinus $(180^\circ-2\propto)$, *where* $\propto$ *is the angle the inclined members make with the horizontal chords.*

It is considered evident, that in case: M_c is larger than M_v+M^i cosinus $(180^\circ-2\propto)$ the chosen depth is too small, and *vice versa* if M_c is smaller, then M^v+M^i cosinus $(180^\circ-2\propto)$ the chosen depth is too great.

Before we proceed with the interpretation of this exceedingly simple relation, we must make a few remarks on its generality.

The material of which we have been speaking is evidently only the variable part of the material in each set of members, and does not include the material used in joints, splices, etc., which would remain the same for a slight change in height; but the variable part is easily selected from a bill of quantities.

In a triangular truss, with no vertical members, M_v is equal zero, when the triangular truss has vertical ties from the upper joints, or vertical posts from the lower joints, to shorten the length of the compressive top chord members, the material in these would be equal M_v. In a truss with more than one system of diagonals, the end diagonals, which have a different inclination from the other diagonals, have of course to be multiplied by their corresponding coefficient; in trusses with inclined end posts or sloping end diagonals, these end posts or diagonals come in under M_i.

In this way, and considering the mode of deduction, we see that our relation is quite general and holds good for any kind of straight truss.

We must now proceed with the discussion of our relation:

$$M_v+M_i\text{ cosinus }(180^\circ-2\propto)=M_c \quad (I)$$

A mere look at this relation shows, that the second member can be positive, zero and negative for different values of $\propto$. The point of transition where this member disappears is of special interest.

The second member disappears for

$$cosin\ (180^\circ-2\propto)=0, \text{ or for } \propto=45^\circ$$

in this special case our relation assumes the very simple form $M_v=M_c$, that is; *when in a rectangular truss* 45° *shall be the most economical angle then must the material in the chords in amount be equal to the material in the posts.*

When $\propto$ is smaller than 45° the second member becomes negative, and when $\propto$ is larger than 45° then the second member is positive, or we might see: *if the diagonals have an angle of inclination less than* 45° *the material in the diagonals decreases for an increase in height,* whereas; *if the diagonals have an inclination to the horizontal chord larger than* 45° *the Web material increases with an increase of height.*

As now in American bridges with long pannels the weight of the chord material will nearly always exceed the weight of the vertical members, we see that for such bridges 45° is not an economical angle but the diagonals would have to make a larger angle with the horizontal chords.

If the angle was still smaller the weight in the chord + part of the weight

of the diagonals would have to be equal to the weight in the posts.

Bridges with many and short panels require a small depth, as here the weight of the posts and part of the diagonals form a greater part of the whole weight, than they do in bridges with few and long panels.

Although as already stated it is not our aim to try a priori to determine the most economical depth, we might still draw a few simple conclusions from our relation. I shall only point out some of these conclusions, as every engineer might easily himself be able to see their justification.

We might see, that the most economical depth is smaller for deck bridges, than for through bridges as the strains on the posts are heavier in the former, than in the latter, (we shall later see another reason). We further see that rectangular trusses with inclined end-posts (or sloping end diagonals) require smaller depths than such with vertical end posts; we see that trusses with more than one Web system might be built deeper than such with only one system of diagonals; we see too that continuous bridges ought to be built lower than single girders; this fact was first pointed out by Mr. Charles Bender.

We have still to consider one special case, namely, the triangular truss with no vertical members, and with an angle of inclination of 45°.

In this case our relation assumes the seemingly absurd form $Mc=0$; but this is not at all absurd, but shows us plainly, that 45° can never be an economical angle for triangular trusses; we could see this in another way easily. We have seen that for $\alpha=45°$ a slight change in the height does not alter the quantity of material in the diagonals, but such a change would change the material in the chords, and if we were to increase the height we would diminish the material in the chords and not change it in the *Web* at all and hence a higher truss would be more economical. We might easily from our relation draw the conclusion that for triangular trusses the most economical depth is a good deal greater than for rectangular trusses.

It is now an easy work to make out a small table of values of cos. $(180°-2\alpha)$ for different values of α and with such a little table at hand it is an easy and quick work with aid of a strain sheet and bill of quantities to find out if the most economical depth has been chosen or not, and eventually in which direction the assumed depth has to be changed, in order to make the truss more economical.

Before concluding, we have yet to justify the assumptions upon which our deductions have been based :

1/ We have assumed, that the horizontal and transverse bracing is a constant part of the whole material.

As regards the horizontal bracing this is correct ; for although this bracing varies slightly for great changes in depth of truss, it remains constant for small changes and the reader will bear in mind that our deduction is based upon the consideration of extremely small changes; to this assumption, hence, no objection can arise. As regards the transverse bracing, we can say exactly the same as we said about the horizontal bracing, as far as through bridges are concerned; but with deck bridges the case is another.

To deck bridges the length of the transverse rods change with the height, and had hence to be introduced into our calculation; they can be very easily introduced and were only left out for the sake of simplicity and generality. Any how the transverse bracing would have a very small influence, and would tend to make deck bridges a little lower.

2/ We have assumed that for an extremely small change in depth, the dead load does not alter; I cannot imagine that anybody should object to this assumption.

3/ We have assumed that a small alteration in height would not alter the sections in the compressive Web members as long as the strains remain the same. This assumption is justified by the fact, that a very great part of these members have so small sections that they would not be changed, and for the others the radius of gyration could be changed in the same proportion as the length.

In case the radius of gyration for these should be kept the same the material in the compressive Web members would in our relation still have to be multiplied with a coefficient, and in case

of vertical posts this coefficient would have to be:

$$1 + \frac{2}{1 + 3600\, n^2}$$

where n is the ratio of the least radius of gyration to the length. This coefficient is found by using Rankine's formula and a similar deduction to the one which gave us our relation.

4/ We now come to the point, which will indicate the limits for the application of our relation. We have assumed that we could vary our chord sections according to the difference in strain arising from a change in height; although we can nearly always do so with the tensile chord it is not possible for the compressive chord, as we cannot construct such a chord with less section than a certain minimum, which cannot be exactly stated as it may be varied with different modes of construction and with the shapes of iron at disposition. This section would determine the span at which we could commence to vary our section, and I should say for a single track railway bridge under an average specification give us the lower limit for the application of our relation, at about 60′ span, and for light highway bridges with narrow roadway, this limit would lie still higher. An upper limit does not exist. I must still make the, perhaps, unnecessary remark that this relation does not apply to any kind of combination bridges, and for wooden bridges the assumption we have made would scarcely hold good for spans lower than say, 150′ and larger purely wooden trusses will perhaps never more be built, therefore we have only to apply our results to wrought iron bridges.

I hope the relation we have found will, from its simplicity and easy application, be of value to practical bridge engineers.

APPENDIX.

Cotang. α is always a known value as it is the coefficient for the calculation of the chord strains.

I therefore annex a little table giving the corresponding values of cosinus $(180° - 2\alpha)$ or the coefficient with which, in our relation, the material in the inclined members has to be multiplied, for given values of cotang α:

Cotang. α.	Cos. $(180 - 2\alpha)$.	Differences.
0.4	+0.72	.12
0.5	+0.60	.13
0.6	+0.47	.13
0.7	+0.34	.12
0.8	+0.22	.11
0.9	+0.11	.11
1.0	+0.00	.10
1.1	−0.10	.08
1.2	−0.18	.08
1.3	−0.26	.07
1.4	−0.33	.06
1.5	−0.39	.05
1.6	−0.44	.05
1.7	−0.49	.04
1.8	−0.53	.04
1.9	−0.57	.03
2.0	−0.60	

The third column gives differences, which are useful for the interpolation for intermediate values of cotang. α.

ON EVAPORATION AND PERCOLATION.

By CHARLES GREAVES, M. Inst. C. E.

Abstract of Minutes of the Proceedings of the Institution of Civil Engineers.

WHETHER the descent of rain or the ascent of vapor be the more important natural phenomenon may perhaps be a difficult question to decide. There can, however, be no doubt that, hitherto, the study of the first and the measurement of rainfall have received the greater degree of attention. It is with a view to obtain a more systematic, and at the same time practical, series of observations of the latter, that the author has undertaken this paper. After having carried on such observations, he has found them afford new and important information; and he hopes to secure cooperation so as to enlarge the exact knowledge of atmospheric evaporation, now unfortunately very limited.

The quantity of water which the inhabitants of this earth, in any part, have

to deal with is the result of the operation of two series of forces, one tending to increase, the other to diminish it. The measurement of rainfall, by the quantity collected, has always this practical advantage, that it is total and real, and the water in hand is an accomplished fact; but the knowledge of evaporation, as now generally acquired, is merely a deduction from the capacity of the atmosphere to evaporate. The endeavor of the author has been to give this also a practical form, and at the same time to avoid prejudice to the observations by a too frequent emptying of the measuring vessel, or from local and accumulated heat causing undue evaporation in it.

It is the purpose of the author to enter into a discussion of maxima and minima—of total and periodic quantities, such as those of

Rain falling;
Rain percolating through ordinary ground, and re-evaporated from it;
Rain percolating through sand, and re-evaporated from it;
Water evaporated from a water surface by a natural process, and their co-relation.

Ever since the year 1850, the author has felt how desirable it would be to confirm the interesting reports then given by Mr. Dickenson to this institution, on the percolation of rain through a medium representing natural soil, and he resolved to establish a similar guage and register. The guage was set in October, 1851, but suffered some interruption previous to the beginning of 1855, since which time the register has been maintained continuously.

The gauge is on the principle known as a "Dalton Gauge," and is thus constructed: A strong slate, open-topped, water-tight box or tank, with an area of one square yard, and one yard deep, has connected to the middle of its bottom a lead pipe, which is led to another fixed vessel with a close bottom, set upright as a receiver, and with its base placed several feet below the tank. A glass guage pipe is fitted to the side of the receiver, with stop and outlet cocks and a graduated scale, and the whole of the receiver is easily protected from frost. The slate tank is sunk into the ground, the inside of the bottom is slightly coned with cement to the mouth of the outlet pipe, and the tank is filled with soil or earth to within two inches of the top. The soil is turfed over, kept level, and the grass is occasionally cut; nothing is done to tighten the soil, and worms are sometimes seen. The water in the receiver never reaches the level of the bottom of the tank, the soil of which is underdrained.

The "Dalton Guage" has no overflow, and water has never been seen to accumulate on the surface of the earth or grass. It is intended that all rain that falls on it should soak in. The soil has once been taken out of the tank and put in again.

A rain guage of equal superficial area, but only one foot deep, was fitted at the same time beside the "Dalton Guage," and the two are under like conditions in all respects.

In the year 1860, another guage, similar to the "Dalton," was established, and filled entirely with fine sand. This was with a view of getting at a definite maximum of percolation. The sand is also underdrained, and is therefore never in a state of stagnant saturation.

The observations from the above gauges did not afford all the knowledge required by the engineer to ascertain the amount of water available out of any known rainfall. They gave the rainfall, the percolation, and, by deduction, the evaporation, both from sand and from a surface of turf; but the evaporation from a water surface is wanted. This has been practically measured, since the end of 1859, in a similar guage, one yard square and one foot deep, which has been kept afloat and partially immersed in a quiet part of a flowing stream. The surface of the water within is always below that of the water without, and from three inches to seven inches is found to be the best depth, this being ascertained periodically with a dip-stick. It is exposed to all weathers, and any addition or abstraction of water is duly recorded, none being made without necessity.

By combining together the observations in the ordinary closed rain guage and those of the floating gauge, an absolute measure of evaporation, from a water surface representing as nearly as

can be the surface of a river, lake, or reservoir, is obtained.

The gauges stood at Lee Bridge, in the valley of the Lee, one and a half miles west of, and six miles north from the meridian of Greenwich. The surface is about ten feet above Trinity high-water level. They are read at 9 A.M., and the records are booked to the day on which they are read.

By the use of the floating gauge the series of comparisons is greatly extended, and the relative proportion of evaporation from land and from water during varying seasons is conspicuously shown. It is not of course possible to affirm that the soil in the "Dalton" gauge is strictly representative. It was intended to resemble common Hertfordshire land, and was made up of soft earth with loam, gravel, and sand, all well mixed up beforehand and trodden in. Neither is it possible to assert that in every respect, and, at all times, the evaporation guage has as accurate a relation to evaporation as rain guages have to rain. Indeed, simple as they are, they have given occasion for a great variety of opinions.

The measurements in the floating guage show directly a gain or a loss of water, and by combining the observations with those of the ordinary closed rain guage the total evaporation is known. A rise of level in the water of the float is recorded as R, a fall as E. The formula for the use of the gauge is then total evaporation from water = R. G. (that is rain guage) $\mp \frac{R}{E}$. A Table of total evaporation is thus obtained.

Comparison with the records of neighboring rain gauges, as published by Mr. G. J. Symons, confirms the accuracy of the Lee Bridge returns. The average fall of rain at twelve stations in London for the seven years, 1864 to 1870, all agreeing closely together, was 24.486 inches; and at Lee Bridge, for the corresponding period, 23.934 inches.

Condensation of moisture on the surface of the sand guage is of frequent occurrence. Only in three years out of the fourteen has the annual evaporation from water exceeded the rainfall, viz., in 1861, 1864, and 1868; in the year 1870 it was the same, and in the remaining years rain was in excess. The rise of water in a supposed tank open to rain and evaporation has been 71.5 inches in fourteen years. The percolation through ordinary ground has been 26.57 per cent. of the rainfall in twenty-two years, and the evaporation 73.42 per cent. of the rainfall. The evaporation from a surface of water has been 77.77 per cent. of the rainfall: still in 1861, 1864, and 1868, the evaporation exceeded the rainfall. In such years the inability to store water, and the loss of store, are severely felt. The actual disappearance of a depth of 11.375, inches of water in seven months in 1868, of 10.625 inches in five months in 1870, of 9.375 inches in five months in 1864, and of 9.125 inches in seven months in 1861, from the surface of an inclosed area of water, by simple evaporation, is a feature that may disturb many calculations. A comparison of tables of evaporation and of rainfall is of great value to an engineer, as showing what can and what cannot be retained in an open receptacle subject to atmospheric influences. If evaporation were the purpose or the end sought, more effect could be attained by excluding the rain, if such could be done without hindering the access of sunshine and of air, but that is not the object. Clearly if an open vessel loses water it does so notwithstanding the rain. Evaporation is the difference between the amount of water in the covered and uncovered rain gauge if that in the latter gauge rises or gains, but the sum of the covered and uncovered gauges if that in the latter falls. If, therefore, evaporation is shown notwithstanding the inclusion of rain, it follows that the theoretical power of the air to evaporate is equal to the same amount inclusive of the rain gauge. The author has not endeavored to draw out the correspondence between humidity and evaporation. His object has been to get at a real result by a practical method, and so to design the apparatus that it may be capable of reproduction by other observers. With this view he has established another gauge, three feet square, and has floated it in a second five feet square. This method is within the reach of all inquirers, and independent of rivers or mill streams and their special difficulties.

PERCOLATION.

The yield of springs, or the abundance

of water in a river, where the river is fed from springs, will be found, from a comparison of the tables in the Appendix, to be dependent more closely on percolation through the soil than on the mere rainfall; indeed it will be found to correspond with percolation. For, whereas the variations in annual rainfall are as 2.33 to 1, being 37.166 inches in 1872 as compared with 15.891 inches in 1864, the annual percolation through ground varies as 3½ to 1, the greatest being 12.587 inches, the least 3.761 inches, in fourteen years. The percolation through sand varies as 7 to 4, being 30.050 inches in 1872, and 12.636 inches in 1864. The evaporation from a surface of water varied only from 26.933 inches to 17.332 inches, being nearly as 7 to 4½ in fourteen years, but it is the intermitting character and its total absence in summer which are so specially characteristic of percolation. Great percolation supervenes on the thawing of snow, and the greatest is due to frequent thaws of small falls of snow. For many consecutive months there is often no percolation whatever, and the monthly range varies from 3.5 inches to nothing. Five times there has been no percolation for seven continuous months, and twice more for six months, and only in one year, 1860, has there been percolation every month.

A thoroughly underdrained soil, if sufficiently flat, would rarely produce any flood, that is, no water passing off by open water-courses. It would resemble the percolation gauge. The result of such underdraining on rivers would be to diminish floods, without lessening the annual discharge of water, and therefore to maintain the flow in dry seasons. Hollow draining does not diminish the perennial flow of rivers as much as improved superficial draining.

The author believes thirty-six inches to be ample depth for a percolation gauge, and he is inclined to think that all water that passes a depth of twenty-four inches in the earth is safe from loss. It is, indeed, doubtful whether in the latitude and temperature of London capillarity has more than a negative action beyond twelve inches in depth. Probably on a moderately free soil the depth from which water is raised by capillarity is but a few inches, and in this may lie the difference in the healthiness of soils, the higher capillary power of a clay soil producing a constant summer exhalation. Whether the substrata underlying a clay soil are really deficient in moisture is a question not sufficiently determined; but the fact, if proved, would be an additional reason for hollow draining, speaking in the interest of agriculture or vegetation.

In order to bring the data into better practical use, the author has reduced each of the tables (omitted for want of space) into a twelvemonthly series, so as to show at the end of every quarter the result for the twelve months previous. By this means a series is produced with a continually uniform term, in which all the seasons take part. The effects of the four previous seasons, which always leave their mark on the earth, on vegetation, and on the climate, are thus continually imported into view. It does not appear needful to carry this form of table over a greater interval. It is possible that percolation, or the absence of it, at one period may have an influence extending over more than twelve months, but it is not habitually so. A wet winter will give abundant springs in the following autumn; but if that is followed by a dry winter, the latter will obliterate the effect of the previous wet winter.

The general conclusions from these records, and the most prominent results observable, are then:—The magnitude of percolation through sand at all times —the smallness of percolation through earth on the whole—the consequent magnitude of evaporation—the entire absence of percolation in warm summer weather—the excess of evaporation from ground over evaporation from a surface of water in winter, and from a surface of water over evaporation from ground in summer—the small thickness of earth under which the water may be considered safe from loss—great variations observable in the twelvemonthly percolation, the maximum reaching ten to eleven times the minimum. Evaporation from earth approaches uniformity from year to year. It hardly reaches 2 to 1, seldom exceeds twenty-five inches or falls below seventeen inches. Evaporation from water is the most uniform of all, the range only just exceeding 3

to 2, the maximum being 27 inches and the minimum 17 inches.

Districts more or less rainy have their special characteristics, known occasionally by popular observation and report, and more exactly where any system of recording has prevailed. Thanks to Mr. Symons' excellent and laborious records, the whole of Great Britain may now be mapped out into rain districts or zones; and if the rate of evaporation were equally well known, it would be possible to distinguish between dry and damp districts. The standard of evaporation and of percolation for any place will become hereafter as much a subject of study as that of rain.

Predictive meteorology is far removed from practical engineering, nevertheless the percolation gauge gives a most certain scale of the future state of springs. The delivery flow of water from springs in the autumn, and consequently the fulness of rivers so fed, is maintained by the rainfall of the previous winter. Summer percolation is nil; and rivers, except as influenced by the rain of the time being, will be short indeed in September and October, if the percolation of rain has not been considerable in the previous December, January or February. Intermittent springs are developed according to the previous percolation, and not simply according to the rainfall, with which they sometimes do not agree at all. Heavy rains in summer may afford no percolation, and a whole year may be considered wet, and yet not be one in which springs are fed. The quantity of water evaporated gives a scale of the capacity of the atmosphere for evaporation, and consequently of the degree of its humidity.

An artificial table for the Home Counties, gives 18 inches of evaporation from the surface of the ground, out of 25 inches of rainfall; that is 72 per cent., or 28 per cent. for percolation. The evaporation from a surface of water is at the same time 82 per cent., leaving 18 per cent. as the gain in rain. The percolation feed, therefore, in what is assumed to be a thoroughly-drained soil and subsoil, is greater than the direct feed on open water alone, as deduced from the balance of rain and evaporation.

After all, it may be argued that the author's gauge is not the best, is not correct, is liable to accumulated and accidental heat—the bane of so many gauges; or that it is open to a double defect, of evaporation in excess in hot weather, and in defect in cold weather. Doubtless water in a shallow vessel is liable to become heated; but the surface of any water becomes heated, and the penetration varies with the depth, transparency, foulness, weediness, wind, waves, and movement, if a river, a mill-stream, or a slow canal, or a ponded river. The author is sanguine that his gauge is a good mean representative of all conditions. It was for some years in a more exposed situation, and appeared during a gale to be in so great danger of receiving the spray from waves dashing against the sides, that it was removed into a more quiet place. Certainly the less oscillation it suffers the better, as in an opposite way the wetting and drying of the inner surfaces must be a source of error, but a counter-action may be found in condensation at other times. Cases of negative evaporation in the floating gauge—that is, of increment above the rainfall—are not numerous; only three occurred in the fourteen years. But on the sand gauge it is frequent, owing to the great degree of cold which the sand evidently acquires. This induced cold causes condensation. Reverse evaporation, or more percolation than rainfall, has never appeared from the ground gauge.

CAST IRON CHILLED WHEELS.—The use of chilled cast iron wheels for railway carriages and trucks is so universal in the United States that on most of the railways no other class of wheel is used to any extent for either passenger or freight rolling stock. In making these wheels, the greatest improvement of late has been the addition to the pig iron in the cupola, a certain proportion of Bessemer steel, usually the crop end of rails, an improvement which was introduced by Mr. Hamilton, and which it is found not only improves the chilling properties of the wheel, but also adds greatly to its strength, and even allows of anthracite pig iron being employed instead of the charcoal iron which previously was always used.

ON THE ORIGIN OF WINDINGS OF RIVERS IN ALLUVIAL PLAINS, WITH REMARKS ON THE FLOW OF WATER ROUND BENDS IN PIPES.

By Prof. JAMES THOMPSON, LL. D., F. R. S. E.

Proceedings of the Royal Society.

In respect to the origin of the windings of rivers flowing through alluvial plains, people have usually taken the rough notion that when there is a bend in any way commenced, the water just rushes out against the outer bank of the river at the bend, and so washes that bank away, and allows deposition to occur on the inner bank, and thus makes the sinuosity increase. But in this they overlook the hydraulic principle, not generally known, that a stream flowing along a straight channel and hence into a curve must flow with a diminished velocity along the outer bank, and an increased velocity along the inner bank, if we regard the flow as that of a perfect fluid. In view of this principle, the question arose to me some years ago:—*Why does not the inner bank wear away more than the outer one?* We know by general experience and observation that in fact the outer one does wear away, and that deposits are often made along the inner one. *How does this arise?*

The explanation occurred to me in the year 1872, mainly as follows:—For any lines of particles taken across the stream at different places, and which may be designated in general as A B, if the line be level, the water pressure must be increasing from A to B, (inner side of bank to outer side), on account of the centrifugal force of the particles composing that line or bar of water; or what comes to the same thing, the water-surface of the river will have a transverse inclination rising from A to B. The water in any stream-line,* at or near the surface, or in any case not close to the bottom, and flowing nearly along the inner bank, will not accelerate itself in entering on the bend, except in consequence of its having a *fall of free level* in passing along that stream-line†.

But the layer of water along the bottom, being by friction much retarded, has much less centrifugal force in any bar of its particles extending across the river; and consequently it will flow sidewise along the bottom towards the inner bank, and will, part of it at least, rise up between the stream-line and the inner bank, and will protect the bank from the rapid scour of that stream-line and of other adjacent parts of the rapidly flowing current; and as the sand and mud in motion at the bottom are carried in that bottom layer, they will be in some degree brought in to that inner bank, and may have a tendency to be deposited there.

On the other hand, along the outer bank there will be a general tendency to descent of surface-water which will have a high velocity, not having been much impeded by friction; and this will wear away the bank and carry the worn substance in a great degree down to the bottom, where, as explained before, there will be a general prevailing tendency towards the inner bank.

Now, further, it seems that even from the very beginning of the curve forward there will thus be a considerable protection to the inner bank. Because a surface stream-line, or one not close to the bottom, flowing along the bank which in the bend becomes the inner bank, will tend to depart from the inner bank at the commencement of the bend, and to go forward directly, or by some such course, leaving the space between it and the bank to be supplied by slower-moving water which has been moving along the bottom of the river perhaps by some oblique path.

* This, although here conveniently spoken of as a stream-line, is not to be supposed as having really a steady flow. It may be conceived of as an average stream-line in a place where the flow is disturbed with eddies or by the surrounding water commingling with it.

† It must be here explained that by the *free level* for any particle is to be understood the level of the atmospheric end of a column, or of any bar, straight or curved, of particles of statical water, having one end situated at the level of the particle, and having at that end the same pressure as the particle has, and having the other end consisting of a level surface of water freely exposed to the atmosphere, or else having otherwise atmospheric pressure there; or, briefly, we may say that the *free level* for any particle of water is the level of the atmospheric end of its *pressure-column*, or of an equivalent ideal pressure-column.

It is further to be observed that ordinarily or very frequently there will be detritus traveling down stream along the bottom and seeking for resting-places, because the cases here specially under consideration are only such as occur in alluvial plains; and in regions of that kind there is ordinarily*, on the average, more deposition than erosion. This consideration explains that we need not have to seek for the material for deposition on the inner bank in the material worn away from the outer bank of the same bend of the river. The material worn from the outer bank may have to travel a long distance down stream before finding an inner bank of a bend on which to deposit itself. And now it seems very clear that in the gravel, sand, and mud carried down stream along the bottom of the river to the place where the bend commences, there is an ample supply of detritus for deposition on the inner bank of the river even at the earliest points in the curve which will offer any resting place. It is specially worthy of notice that the oblique flow along the bottom towards the inner bank begins even up stream from the bend, as already explained. The transverse movement comprised in this oblique flow is instigated by the abatement of pressure, or lowering of free level, in the water along the inner bank produced by centrifugal force in the way already explained.

It may now be remarked that the considerations which have in the present paper been adduced in respect to the mode of flow of water round a bend of a river, by bringing under notice, conjointly, the lowering of free level of the water at and near the inner bank, and the raising of free level of the water at and near the outer bank relatively to the free level of the water at middle of the stream, and the effect of retardation of velocity in the layer flowing along the bed of the channel in diminishing the centrifugal force in the layer retarded, and so causing that retarded water, and also frictionally retarded water, even in a straight channel of approach to the bend, to flow obliquely towards the inner bank, tend very materially to elucidate the subject of the mode of flow of water round bends in pipes, and the manner in which bends cause augmentation of frictional resistance in pipes, a subject in regard to which I believe no good exposition has hitherto been published in any printed books or papers; but about which various views, mostly crude and misleading, have been published from time to time, and are now often repeated, but which, almost entirely, ought to be at once rejected.

* That is to say, except when by geological changes the causes which have been producing the alluvial plain have become extinct, and erosion by the river has come to predominate over deposition.

DAMS FOR RESERVOIRS.

By WM. J. McALPINE, C. E.

Journal of the American Society of Civil Engineers.

In regard to the construction of earthen dams for reservoirs; below is a copy of the specifications for restoring the earthen dam at Worcester. These are full enough to explain my views of how an earthen dam should be built.

I have a letter from one of our most experienced and judicious members, in which he says: "It is a mortifying fact that so many of the dams built by our engineers in this section have failed, though those built by farmers and mill-owners stand safe."

Another said to me: "It is an accident if any earthen dam which has a 'spiling wall' does not fall." And another, referring to river dams of stone or wood, said: "They can never be considered safe until they have been twice carried away" (*i. e.*, at each end).

Earthen dams rarely fail from any fault in the artificial earth work and seldom from any defect in the natural soil. It, the latter, may leak, but not to endanger the dam. In ninetenths of the cases the dam is breached along the line of the water outlet passages.

The "spiling walls," which are put in

so many earthen dams, extending the whole length of the embankment and form a base into the tight natural soil and up to a level above the water in the reservoir, is usually made of rubble stone laid in cement with smooth faces.

Such walls will not perceptibly settle, but the best built puddle placed alongside will settle considerably, and there will always be a vertical crack along the whole length and height and at both faces of the wall.

If there should happen to be any place in the upper half of the dam which leaks, these cracks will conduct the water to an indefinite distance along, under and on both sides of the wall, to some leaky portion in the lower half where the water can escape.

A mere film of water is sufficient to carry the whole pressure (not volume) from the lake, and the water escaping in muddy sweat drops is gradually carrying with it the light soil in solution and enlarging the passage until an increase of quantity takes up the earth in suspension, and the orifices are then rapidly enlarged and a breach threatened.

Hence such cut-off walls become sources of danger. The two materials (masonry and earth) should not be used together if it can be avoided, or if so used, extraordinary care should be taken to prevent even a film of water along the line of union.

The outlet passages must be of masonry or of iron, and should rest on and be enveloped in masonry, and extending transversely through the dam is a source of peculiar danger.

Water in motion "abhors an angle" and any head can be destroyed by forcing the water to turn a sufficient number of abrupt angles, at each of which the velocity is lessened, the quantity (leakage is less, the "solution" or "suspension" is less and the danger of breakage is diminished and, with a sufficient number, is prevented.

Wherever walls of masonry are in contact with earth a film of water communicating with that in the reservoir is liable to occur. The surfaces of these walls should be made as rough and irregular as possible to produce as many of these angles as possible.

The puddle walls are always founded into a trench in the natural soil which should be broken up, and it should also be "toothed" both horizontally and vertically when the wall is *stepped* up on the sides of the ravine.

Under the whole base of the embankment, or, at least, that portion from under the lower top angle to the foot of the water slope, should be prepared by removing the pervious or decaying matter by breaking up the natural soil, and by stepping up the sides of the ravine, but also by several "toothed" trenches across the bottom and up the sides.

Forty years ago, Mr. Jervis introduced the modern system of building earthen banks, but before that time the "old school" engineers built earthen dams which rarely failed. Our modern practice requires the artificial earth work to be made with extraordinary care, but then it must always be based upon the natural soil. Now we take this same soil, select it carefully, moisten and compact it at great expense, and yet it is subjected to less pressure than the underlaying natural soil. Is all this care necessary? I never heard of a case where a dam failed from an imperfection in the artificial earth work, even if built by a "farmer." Leakages and destruction come from an imperfect connection between the artificial and natural earths.

The failures of earthen dams from overflow are not uncommon. No such dam is safe unless it has an overflow long enough to discharge the heaviest rain fall (increased by melting snow) without resort to the manual operation of opening gates, etc., before the water can rise to within three to five feet of the top of embankment. The attendant may be taken suddenly sick, or may be absent or sleepy, and the dam is destroyed.

Specifications for repairing the break in the dam of the storing reservoir for the Worcester water works, on Lynde brook, in the town of Leicester:—

General description.—The former dam was made of fifty feet width on top, and slopes on each side of two horizontal to one vertical, and forty feet above the base. It was arranged that it could be hereafter built to a level five feet higher, which would have reduced the top width to thirty feet. Although the dam now remaining is of unnecessary width on the top, yet for appearance sake the same

outlines will be maintained in the new work of repairs.

The space opened by the breach will be filled with an earthen embankment, in the middle of which will be a puddle wall, and transversely through the bank will be placed three lines of cast iron pipes resting upon and enveloped in a wall of rubble masonry and connected with three cast-off walls of masonry. At the upper end of the pipes, near the foot of the upper slope, will be erected a regulating gate house, and near the foot of the lower slope, a gate well, both of rubble masonry. The upper face of the new embankment will be protected by a slope wall pavement of the same character as that now upon the face of the old dam. The present waste way will be maintained as heretofore, except that the provision for the insertion of flash boards will be removed. The new gate house will be arranged to act also as an additional waste way, discharging at the same level as the present weir.

The important features in the restoration of the dam consist:

First.—Of the removal of the whole of the bottom part of the former "spiling walls."

Second.—Of cutting off six feet in length of the original supply and waste pipes directly under the new puddle wall.

Third.—The founding of the bottom of the new puddle wall into the water-tight original soil by toothing, as shown on the plans, and by jutting vertically and horizontally into the steps with the same toothing. Where the former banks are found to be of good material and to have been carried down into water-tight natural soil, and when such banks have not been disturbed by cracks and slides, they are to be considered as equal to the natural banks, and the puddle wall is to be founded, toothed, and stepped into them, as before mentioned, for the water-tight natural earth.

Fourth.—The new embankment above the center line of the dam will be founded by stepping into toothing and jutting, as described for the puddle wall, but to a less extent; that is, the jutting may be made at intervals of ten feet (transversely to the line of the embankment), and from two to four feet deep and back into the present banks*.

The stone for the gate house and gate well should be of sound, durable, well shaped and large sized stone, such as will make good rubble masonry, and give a good, fair, regular face on the outside and inside of the gate house and well. The whole to be well bonded and laid up compactly in mortar of hydraulic cement. The waste or overflow at the level of top water in the reservoir may be made of the cut stone blocks from the old gate house, and any surplus of such cut stone may be laid for the quoins of the upper portion of the well. The foundation of the gate house, should be made of sound, durable timber and plank, placed at such depth as to be always wet.

Seventh.—The selection of the material should commence at the borrow pit by using the best of the material, breaking up the lumps and throwing aside all stones of more than two inches in diameter. When the earth is deposited alongside of the puddle wall, the same selections and breaking up are to be continued, and again when it is strewn.

The puddle wall should be made as follows: The selected materials deposited (the clay soil on one side and the fine gravel on the other side) along the wall should be distributed by strewing thin layers with the shovel, giving the proper proportion of each by having three men strew the clay and one the gravel, and a fifth man sprinkling with water (being careful to avoid any excess of water), until a depth of six inches is obtained.

When the puddle stuff has been thus prepared and tempered with water, it is to be cut and cross-cut with spades, in cuts of not exceeding one inch in width, taking care that the spades are forced down into the lower course of puddle to thoroughly incorporate the whole mass.

In rainy weather, or when too much water has been used, so as to make the puddle quake like jelly, it must be allowed to remain undisturbed until the excess of water is carried off by absorption and evaporation. Whenever a course of the puddle is finished, and before it can sun-crack, a fresh layer of puddle material must be put on, and whenever the puddle has stood so long as to have lost its moisture, it must be

* Much of the details of the specifications is here omitted.

wet and recut before an upper course is laid on. Carts must not be allowed to pass over the puddle except where planks are laid down.

The puddle wall must be commenced in the lowest place and be carried up in level courses, but the adjacent embankment must always be built up at least six inches higher than the puddle wall.

If necessary (to be avoided if possible) to carry up the puddle higher in one place than in another, it must be done by racking back in steps of not more than six inches depth nor less than two feet tread (four to one).

Eighth.—The upper half of the embankment (made of the selected materials before mentioned) must be built up in level courses of not exceeding four inches thickness, spread evenly by strewing with the shovel and moistening to a proper consistency. The lumps must be broken up fine at the borrow pit, at the dump and when strewn, and a careful selection of the material must be made at each place. The embankment must be commenced at the lowest place, and always be maintained nearly level in both directions, and, if necessary to be built up higher in one place than another, it must be racked back in steps equal to one in four.

The under part of the embankment for ten to fifteen feet high may be made with wheelbarrows; but whether made with carts or barrows each layer must be thoroughly rolled with heavy, grooved rollers before the succeeding one is put on. That portion of the embankment immediately adjoining the puddle wall should be made almost as compact as the puddle wall, and at ten or fifteen feet distant it should taper off in compactness to that of the remainder of the embankment. The lower half of the embankment will be made with the best materials and care, adjacent to the puddle wall, and less care toward the lower slope. The pavement wall on the upper slope has been previously described. It may be laid directly upon the earthen embankment.

Ninth.—The gate house shall be made eight by six on the inside, with walls four feet thick at the bottom, and 2½ feet at the level of top water in the reservoir, and above this there will be arranged a foundation to the house by four brick arches, through which water will flow and wash into the well. The upper house may be of wood or brick, and having access by a small wooden bridge to the top of the embankment. The foundation of the gate house will be eighteen by sixteen feet of pine timbers about eight by twelve inches, covering half the area, and covered with two inch pine plank. The outside wall will be provided with three small waste holes of one foot square, closed with a three inch plank placed on the foundations. The inlet gates will be of cast iron two by three feet, sliding vertically on cast iron frames, three of which will be placed on the upper face of the gate house wall, and protected by a timber and plank frame with wooden screens. In the middle of the inside chamber a strong frame of wood and plank will be placed and let into the side walls and made water-tight. In this frame will be inserted three cast iron gates of the same size, and provided with iron frames the same as those in the front wall. There will also be a frame with a fine wire cloth screen placed above the gate frame.

The face of the wall through which the iron pipes pass into the gate house will be made smooth, so as to allow a wooden gate to be put down in the water and close up each pipe. These three pipes will be separated in the gate house by two vertical wooden partitions. The third or waste pipe will be arranged by means of a floor above to discharge the waste water only into the partition attached to the waste pipe. All of the gates will be provided with the proper apparatus to raise them and to discharge the supply water into each, or to shut it off from each. The lower gate well will be eight by six feet and eight feet deep, covered with trap doors. Each of the pipes will have a stop gate, and the waste gate a curved iron pipe to the discharge culvert. The pipes will be of cast iron of two feet inferior diameter, and 1¼ inches thickness of metal connected by leaded joints. Where the pipes pass through the cut-off wall and at the gate house, there will be placed an exterior flange of forty-two inches exterior diameter, which is to be leaded to the exterior of the pipe.

THE CENTENNIAL EXHIBITION.

From "Engineering."

NOTWITHSTANDING the somewhat general opinion that the Philadelphia Exhibition would be kept open to the public until the close of November, the doors were shut on the day originally fixed—the tenth—and under very unfavorable conditions of weather the final ceremony of concluding the great show was carried out. It is too early yet to analyze with any accuracy the financial results of the undertaking, but this much may be said, that the number of visitors to the Centennial has far exceeded that of any previous exhibition, and it must be borne in mind that these visitors were composed almost wholly of Americans, and were not made up of all the civilized nations of the world, as has been the case with European exhibitions. The total number of visitors was considerably over 9,000,000, of whom nearly 8,000,000 paid for admision, and the price of entrance, with the exception of a few special days, was fifty-cents., or nearly two shillings, so that the total receipts will have been about £600,000 sterling. This amount, together with the sale of the buildings, amounts paid for concessions, and other sources of revenue, will certainly be quite inadequate to pay the expenses incurred, and a large deficit will doubtless be found to exist, which will have to be made good by the Government and other responsible parties, But that international exhibitions should prove lucrative undertakings is not to be expected; on the contrary, they are almost certain to be attended with heavy losses. If, however, it can be shown that there are direct and indirect benefits arising from an exhibition to the country in which it is held, such benefits must be set against the losses actually incurred, in order to arrive at a fair balance. Thus with the Centennial. It will certainly have cost the United States a large sum, and one of the great indirect advantages attending international exhibitions—that of money spent in the country by foreign visitors—is to a large extent absent. On the other hand, it has thrown into the hands of American exhibitors new and important business connexions, which must bring with them solid and permanent benefit, unshared by other countries, which were practically unrepresented, or rather misrepresented, at Philadelphia. It has been a fitting celebration of the hundreth anniversary of a grand nation, an occasion on which few Americans would stay to count the cost, and it has carried with it those important lessons inseparable from all great displays of industry and art.

But there is another and most important point of view in which to regard the Centennial—and all other international exhibitions—that of the exhibitors. Has it repaid, directly or indirectly, those who have incurred the trouble and expense of sending goods to Philadelphia, of installing them, and representing them during the past season? Generally we should imagine that exhibitors will be repaid. As regards machinery, the show made by foreign countries was so insignificant that the profit or loss was necessarily small. As to American exhibitors we imagine that few will regret the part they have taken at Philadelphia.

We notice in the pages of our contemporary, *The Engineer*, an article (*vide* that journal, page 345, November 17) in which the Centennial and all other exhibitions are sweepingly attacked, and the criticism leveled at the Exhibition just closed, are such as to call for some rejoinder in the names of decency and truth. For some reason or other our contemporary labors under a severe and incurable mania against the United States, its people, and its industry; and writing in a spirit, bred of ignorance and insular prejudice, invents calumnies which it supports by unfounded statements. We have nothing to do here with the broader question of the policy of international exhibitions, but only with the torrent of abuse poured out against the Centennial. We will notice some of these statements in detail. The writer gives exact figures bearing on the charges made to exhibitors for placing their goods in position. They say,

"When we find that it cost about £100 to get a small portable engine from England to its place in the Centennial, no less than £17 being charged for taking it out of a packing case," &c. There was only one portable engine from this country, that exhibited by Messrs Davey, Paxman and Co., who also sent a vertical engine and boiler. With the question of freight from England to the Exhibition grounds we have nothing to do, but the charge for unpacking, erecting, and exhibiting lies before us. It is for both engines, and is as follows:

Unpacking, cleaning, painting, and erecting portable and fixed engines, providing timber platforms.....	$62.75
Signboard.....	19.50
Wages for cleaning, and attendant for exhibiting same through the whole term of the exhibition....	160.00
	$242.25

The engines had suffered in the passage and required considerable cleaning and painting to put them into exhibition order, and the whole charge for this was about £12 for both engines, instead of £17 for one as stated by our contemporary. And this work was done at a time when crowds of exhibitors were eager to unpack their goods, when workmen were scarcely to be obtained, and the almost helpless British Commission did little or nothing to assist their exhibition. In fact, as regards this very exhibit, a notification was sent to the British Commission that the packing cases had been for some days lying unopened, coupled with a request that workmen should be provided for the purpose; but doubtful of the organization at St. George's House, men were at once secured at any cost to work on Saturday night and all day Sunday, so that all was in place on the Monday morning. Some days later a reply was received from the British Commissioner stating that workmen were employed upon the cases; but long before, these men had finished their work and had been paid—by ourselves. To return, however, to *The Engineer:* "On the whole," they say, "we venture to think that the majority of the foreign exhibitors at Philadelphia are exceedingly sorry that they ever went there; and some of them will be yet more sorry when they find that their choicest devices and most exquisite designs are reproduced in the States, and sent to our markets by men who hold, curious as it may seem, that while protection is the best thing in the world, free trade in the ideas of other men is very nearly as good." In other words, that the American national character is so devoid of honesty, that it has invited foreign manufacturers to Philadelphia, that they may be robbed of their ideas, with the result of American copies underselling the originals in foreign markets. It is almost needless to comment on this foolish writing. The above remarks can scarcely apply to machinery, because there was none exhibited from abroad worth copying, and we presume that the "choicest devices and most exquisite designs," refer to fabrics, ceramics, and other art industrial exhibits in the main building.

Now if the writer in *The Engineer* had visited Philadelphia, he would have seen how far behind Europe, America is in its art industries, how many years, it may be even generations, must be passed before pure artistic taste and industrial skill can be developed for the production of the wonderful, though limited results embodied in the English and French exhibits at Philadelphia. The United States is too young, and has been too busy with the stern necessities of life to be able to imitate even faintly European art, and it is to Europe they must look for many years to come, not for devices and designs to steal—the object for which, according to *The Engineer*, manufacturers were invited to the Exhibition—but for manufactured art objects, for which demand in America is rapidly growing, without the least chance of supply except from this side of the Atlantic. What chance is there then that American makers will export their goods to this country, and undersell Minton, Maw, and Doulton, that France need fear for her porcelain or her velvets, that Belgium should tremble for her lace trade, or that the business in Vienna goods should be destroyed by exported American leather work.

The Engineer refers next, in the same narrow-minded spirit, to the difficulties that occured between the Exhibition and our own authorities, and here they have

a certain ground for harsh criticism. Exhibitors had great reason to complain of the difficulties placed in their way, of the vexatious obstacles raised by the Customs, and of many other things resulting from bad management. We suppose, however, that these difficulties were interesting to us only so far as our own exhibitors were concerned. And for them we have to thank the British Commissioner. During his first visit to Philadelphia, Mr. Owen had foreseen them all, and had afterwards matured a scheme for smoothing down the obstacles which shortly became so formidable. But Mr. Owen was removed to make place for Colonel Sandford, who was unfortunately in total ignorance of the duties of a Commissioner, because he was without any experience, and, as all the world knows, it was found expedient to recall Mr. Archer when the Exhibition was half over. But from our knowledge we affirm that had Mr. Owen remained in office, none of the above causes of complaint would have remained unremoved.

We now come to another statement made by *The Engineer*, which we almost hesitate to reproduce: "From first to last there was manifested by the Americans a total absence of generous feeling, not only towards strangers, but amongst themselves." Almost every visitor to the United States during the past summer can testify that the statement is devoid of truth. To all those properly accredited the door of hospitality was opened, and no effort, private or public, was spared to welcome visitors. The Reception Committee of the Society of Civil Engineers and the Institution of Mining Engineers carried out the work entrusted to them in an admirable and liberal spirit, and Mr. Bogart, representing the former, and Mr. Neilson, acting for the latter, were unwearied in their efforts to facilitate the movements and comforts of visitors. Throughout the United States works of all kinds were thrown open to foreigners with a willingnes and freedom unknown in any other country, and the excursions planned and carried out were on a scale suitable to the occasion. We will not dwell on this ungracious effort made by *The Engineer* to repay with insult the generosity of Philadelphia during the past season, and we can only hope in all charity, either that the author of the article wrote in entire ignorance, or that he was one of the insignificant few who could not be included within the extended pale of American hospitality. We pass over the allusions to the incompetency of the judges, to the corrupt American press, and to the "oppressive and insulting" system practised on exhibitors, and go on to the last charge made in this article "of the extortion and rapacity of the good people of Philadelphia," which was declared "scandalous" even by the American press. That this accusation is entirely false, all who visited Philadelphia can testify. Doubtless there were plenty of instances of extortion, but none of these cases occurred in the respectable portions of the city. Hotel charges remained unaltered, and they are far cheaper than are known in this country or on the Continent; the prices of the various American restaurants in the Exhibition were all marked by extreme moderation. Carriage hire is always excessively dear in the United States, though it was no dearer last summer than the year before, but other means of communication—tramways and railroads—are notoriously cheap. We can readily imagine an individual accustomed to a tenth-rate mode of living in this country, and seeking similar accomodation in Philadelphia, might fall into bad hands, and pay twice as much there as in London, but at the large hotels the charges made to include all the requirements of the visitors, ranged from 4 dols. to 5 dols. a day. So far from extortion and rapacity, the householders of Philadelphia have earned for themselves a lasting reputation—as compared with London, Paris, and Vienna—for moderation and fair dealing.

We will reproduce a part of the peroration of this article we have been criticising:

"If it could be shown that any great advantage was gained in return for all the trouble taken by exhibitors at Philadelphia we should have consolation, but we cannot indicate a single benefit reaped by the world in general. . . . If the present state of trade in the States is to be regarded as the result of the Centennial, then all we can say is that

without the Centennial it must have been so bad as to have almost expired altogether. . . . . What has become of the instruction the world was to receive? Where are the thousands of new ideas, American, and therefore very good [observe the sneer], which the Centennial was to impart? We fear that when men sit down solemnly and add up their new ideas, and put their mental acquisitions together, they will find them very few indeed. The American press is to all intents and purposes silent on the subject; the technical journals one and all practically ignored the contents of the Exhibition. . . . Let our readers run over the pages of this journal for the last six months and see for themselves how much that was good and new could be found in the Machinery Hall by our correspondent (! !). . . . The best American engineering firms sent nothing to Philadelphia, and the result was that the American department, as a whole, represented just what we should expect to find in a country not yet very far advanced in the art of construction."

We will not reply to this quotation in our own words, nor in those of several eminent among our countrymen, who have already expressed their impressions of the Centennial Exhibition and of the country of which it was an exponent, but we will quote from an article written by Mr. Simonin, so well known in the metallurgical world, and recently published in the *Revue des Deux Mondes:*

"It therefore but remains to be inquired into what general teachings the visitor had derived from the great show, especially the European visitor. We may sum up the lesson to the following effect: Thanks to the fertility of her soil, and the facilities of conveyance on land and water, America is now enabled to feed Europe with her grain, flour, and provisions—nay, with live cattle, as she has hitherto already furnished us with cotton. The productiveness of her mines of imcomparable abundance enables her to do without Europe as regards pig and merchant iron, steel, copper, and most of the remaining metals of commerce. She constructs her own machinery and most of the other manufactured goods. But this does not prevent her from shipping to Europe the precious metals which we require for all our transactions, and which the new world turns out as abundantly as the rest of the world put together. As regards coal, to be seen at Philadelphia in blocks of enormous size, America will soon produce of it as much as England—or rather, as much as the rest of the world, her deposits being twenty times the size of those of England.

"This economical lesson seems to us the most striking one we have drawn from a two months' stay at the Exhibition. America will more and more learn to dispense with Europe, while the latter cannot do without America. It is, indeed, a New England which rises beyond the seas, and which already threatens old England in all the markets of the world in the extreme East—Japan, China, perhaps British India, as well as in South America. Although France is not equally as much interested in the struggle that is thus inaugurated as England, yet she is forewarned and begins to feel it. Even our wines and brandies the American vineyards begin to vie with. Only connoisseurs can perceive the difference."

To those indeed who are able to learn anything, the Centennial has taught an all-important lesson. It has brought under our immediate notice a great people, clear-sighted, full of energy and business instincts, owning a vast territory, the natural riches of which throw those of Europe utterly in the shade. Almost every range of climate, every class of soil, probably every mineral product, are met with between the limits of her boundaries. The progress she has made in a hundred years, despite the almost incredible obstacles thrown in her way by nature—and not the least of which have been her "magnificent distances"—affords us a scale by which to measure her advance in another century, an advance which will be incredibly more rapid, when political difficulties which harass the country on every side shall have disappeared. Every year sees the United States not only more independent of Europe, but approaching to the period when she shall become a serious competitor with European manufactures—an important fact which the Centennial ought to have impressed upon all its foreign visitors.

The Engineer remarks that the best

American firms sent nothing to Philadelphia.

What then are the Baldwin Locomotive Works, Sellers, Corliss, and a host of others we could name prominent amongst American manufacturers and exhibitors? True, many conspicuous names were absent, some from the result of accident, like W. B. Bement and Son, others on account of the dullness of trade which has for so long depressed American industry, and who, had the Exhibition taken place a few years earlier or later, would have been represented.

We do not seek for the true motives which have led our contemporary into making criticisms so unfair and so devoid of truth, as those against which we have protested. It is not long since an article denying the right of Americans to rank as inventors, appeared in its columns, and which called forth a rejoinder from a prominent United States Journal, the opening and concluding remarks of which apply equally to the present case: "Such statements as the above, however qualified, can only be characterized as a silly exhibition of 'spleen,' and a journal which has any respect for itself, or for truth, should be ashamed to admit to its columns, much more to print it as editorial opinion. . . . We concede our obligations to the mother country, but when a representative British journal asserts that the world is under no obligations to us for valuable discoveries and inventions, it manifests either dense ignorance or egregions vanity."

ON SOME OF THE CHANGES IN THE PHYSICAL PROPERTIES OF STEEL, PRODUCED BY TEMPERING.

By Prof. A. S. KIMBALL.

From "The American Journal of Science and Arts."

A few interesting, and, to a certain extent, novel results have recently been developed in our laboratory, which I venture to present in their present incomplete form, since the pressure of other duties will postpone, for a few months, further investigations in this direction. Up to the present time the larger number of our experiments have been made upon the behavior of tempered bars under a transverse stress, although a few qualitative trials have been made upon changes in electric conductivity and coefficients of expansion.

I. *The modulus of elasticity decreases as the hardness of the steel increases; in other words the harder the bar, the greater the deflection produced by a given weight.*

Many manuals of practical mechanics give a higher modulus for tempered than for untempered steel. Reuleaux in "Der Constructeur," (page 4,) states that it may be increased fifty per cent. by hardening. Coulomb and Tredgold state that hardening has no influence whatever, while Styffe finds that the modulus is diminished. For our first experiment, five pieces of good tool-steel, each 13″ long, were cut from a half-inch square bar. These were carefully annealed, squared, and polished. No. 1 was laid aside and the others were hardened in cold water in the usual manner; No. 2 was "drawn" on a hot plate to a dark blue; No. 3 to a purple; No. 4 to a straw color; No. 5 was left hard. The modulus of elasticity was then determined by measuring the deflection produced by a weight applied at the middle of the bar. The probable error of the experiments did not exceed one-fifth of one per cent. The experiment was varied in many ways, several qualities of steel and bars of different dimensions were employed with uniform results. In some grades of steel a difference of more than ten per cent. has been found between the modulus of the hardened and that of the annealed bar.

II. *The increase of deflection in a given time is greater the harder the steel.*

It is well known that the deflection of a bar left under stress will increase for a

long time. I am not aware, however, that comparative tests of the rate of increase in steel of different tempers have previously been made.

III. *The immediate set increases with the hardness of the steel.*

In the experiments each bar was of course loaded with the same weight which was allowed to act for the same number of minutes.

IV. *A bar recovers from a temporary set with greater rapidity the harder it is.*

The remarkable fluctuations in the line of the bar observed by Prof. Norton, (this Journal, April, 1876,) became more marked and had a wider range as the hardness of the bar increased. In none of the experiments referred to was a permanent set produced, though in some cases forty-eight hours had elapsed before the bar recovered its original line. In a few experiments an attempt was made to determine the approximate hardness of the bars by grinding. The results obtained, however, could not be considered very reliable. A more satisfactory method was found in the determination of the temperatures employed in hardening and drawing, by the specific heat of platinum, or by the use of the pyrometer.

I am indebted to Mr. F. C. Blake for the accuracy with which the experiments referred to in this note, have been conducted.

PREHISTORIC ART AND SCIENCE.*

From "The Architect."

It is a somewhat curious fact that, while all modern writers admit the great antiquity of man, most of them maintain the very recent development of his intellect, and will hardly contemplate the possibility of men equal in mental capacity to ourselves, having existed in prehistoric times. This question is generally assumed to be settled, by such relics as has been preserved of the manufacturers of the olden races, showing a lower and lower state of the arts; by the successive disappearance in olden times of iron, bronze, and pottery; and by the ruder forms of the older flint implements. The weakness of this argument has been well shown by Mr. Albert Mott in his very original but little known presidential address to the Literary and Philosophical Society of Liverpool in 1873. He maintains that "our most distant glimpses of the past are still of a world peopled as now with men both civilized and savage," and, "that we have often entirely misread the past by supposing that the outward signs of civilization must always be the same, and must be such as are found among ourselves." In support of this view he adduces a variety of striking facts and ingenious arguments, a few of which I will briefly summarise. On one of the most remote islands of the Pacific—Easter Island—2,000 miles from South America, 2,000 from the Marquesas, and more than 1,000 from the Gambier Islands, are found hundreds of gigantic stone images, now mostly in ruins, some thirty or forty feet high, while some seem to have been much larger, the crowns on their heads cut out of red stone, being sometimes ten feet in diameter, while even the head and neck of one is said to have been twenty feet high. These once stood erect on extensive stone platforms, yet the island has only an area of about thirty square miles, or considerably less than Jersey. Now as one of the smallest images eight feet high weighs four tons, the largest must weigh over 100 tons, if not much more; and the existence of such vast works implies a large population, abundance of food, and an established government. Yet how could these coexist in a mere speck of land wholly cut off from the rest of the world? Mr. Mott maintains that this necessarily implies the power of regular communication with larger islands or a continent, the arts of navigation, and civilization much higher than now exists in any part of the Pacific. Very similar

* Address of Mr. A. R. Wallace, President of the Section of Biology of the British Association.

remains in other islands scattered widely over the Pacific add weight to this argument. The next example is that of the ancient mounds and earthworks of the North American continent, the bearing of which is even more significant.

Over the greater part of the extensive Mississippi valley four well-marked classes of these earthworks occur. Some are camps, or works of defence, situated on bluffs, promontories, or isolated hills; others are vast enclosures in the plains and lowlands, often of geometric forms, and having attached to them roadways or avenues often miles in length; a third are mounds corresponding to our tumuli, often seventy to ninety feet high, and some of them covering acres of ground, while a fourth group consist of representations of various animals modelled in relief on a gigantic scale, and occurring chiefly in an area somewhat to the northwest of the other classes, in the plains of Wisconsin.

The first class—the camps or fortified enclosures—resemble in general features the ancient camps of our own islands, but far surpass them in extent. Fort Hill, in Ohio, is surrounded by a wall and ditch a mile and a half in length, part of the way cut through solid rock. Artificial reservoirs for water were made within it, when at one extremity, on a more elevated point, a keep is constructed with its separate defences and water-reservoirs. Another, called Clark's work, in the Scioto valley, which seems to have been a fortified town, encloses an area of seventeen acres, the embankments measuring three miles in length, and containing not less than three million cubic feet of earth. This area encloses numerous sacrificial mounds and symmetrical earthworks in which many interesting relics and works of art have been found. The second class—the sacred enclosures—may be compared for extent and arrangement with Avebury or Carnak—but are in some respects even more remarkable. One of these at Newark, Ohio, covers an area of several miles with its connected groups of circles, octagons, squares, ellipses, and avenues, on a grand scale, and formed by embankments from twenty to thirty feet in height. Other similar works occur in different parts of Ohio, and by accurate survey it is found not only that the circles are true, though some of them are one-third of a mile in diameter, but that other figures are truly square, each side being over 1,000 feet long, and what is still more important, the dimensions of some of these geometrical figures in different parts of the country and seventy miles apart, are identical. Now this proves the use, by the builders of these works, of some standard measures of length, while the accuracy of the squares, circles, and, in a less degree, of the octagonal figures—shows a considerable knowledge of rudimentary geometry, and some means of measuring angles. The difficulty of drawing such figures on a large scale is much greater than anyone would imagine who has not tried it, and the accuracy of these is far beyond what is necessary to satisfy the eye. We must therefore impute to these people the wish to make these figures as accurate as possible, and this wish is a greater proof of habitual skill and intellectual advancement than even the ability to draw such figures. If, then, we take into account this ability and this love of geometric truth and further consider the dense population and civil organization implied by the construction of such extensive systematic works, we must allow that these ancient people had reached the earlier stages of a civilization of which no traces existed among the savage tribes who alone occupied the country when first visited by Europeans.

The animal mounds are of comparatively less importance for our present purpose, as they imply a somewhat lower grade of advancement; but the sepulchral and sacrificial mounds exist in vast numbers, and their partial exploration has yielded a quantity of articles and works of art, which throw some further light on the peculiarities of this mysterious people. Most of these mounds contain a large concave hearth or basin of burnt clay, of perfectly symmetrical form, on which are found deposited more or less abundant relics, all bearing traces of the action of fire. We are, therefore, only acquainted with such articles as are practically fireproof, or have accidentally escaped combustion. These consist of bone and copper implements and ornaments, discs and tubes—pearl, shell, and silver beads, more or less injured by fire—ornaments cut in

mica, ornamental pottery, and numbers of elaborate carvings in stone, mostly forming pipes for smoking. The metallic articles are all formed by hammering, but the execution is very good; plates of mica are found cut into scrolls and circles; the pottery, of which very few remains have been found, is far superior to that of any of the Indian tribes, since Dr. Wilson is of opinion that it must have been formed on a wheel, as it is often of uniform thickness throughout (sometimes not more than one-sixth of an inch), polished and ornamented with scrolls and figures of birds and flowers in delicate relief.

But the most instructive objects are the sculptured stone pipes, representing not only various easily recognisable animals, but also human heads, so well executed that they appear to be portraits. Among the animals, not only are such native forms as the panther, bear, otto, wolf, beaver, racoon, heron, crow, turtle, frog, rattlesnake, and many others, well represented, but also the manatee, which perhaps then ascended the Mississippi as it now does the Amazon, and the toucan, which could hardly have been obtained nearer than Mexico. The sculptured heads are especially remarkable, because they present to us the features of an intellectual and civilized people. The nose in some is perfectly straight, and neither prominent nor dilated, the mouth is small and the lips thin, the chin and upper lip are short, contrasting with the ponderous jaw of the modern Indian, while the cheek-bones present no marked prominence. Other examples have the nose somewhat projecting at the apex in a manner quite unlike the features of any American indigenes, and, although there are some which show a much coarser face, it is very difficult to see in any of them that close resemblance to the Indian type which these sculptures have been said to exhibit. The few authentic crania from the mounds present corresponding features, being more symmetrical and better developed in the frontal region than those of any American tribes, although somewhat resembling them in the occipital outline; while one was described by its discoverer (Mr. W. Marshall Anderson) as a "beautiful skull worthy of a Greek."

The antiquity of this remarkable race may perhaps not be very great, as compared with the prehistoric man of Europe, although the opinion of some writers on the subject seem affected by that "parsimony of time" on which the late Sir Charles Lyell so often dilated. The mounds are all overgrown with dense forest, and one of the large trees was estimated to be 800 years old, while other observers consider the forest growth to indicate an age of at least 1,000 years. But it is well known that it requires several generations of trees to pass away before the growth on a deserted clearing comes to correspond with that of the surrounding virgin forest, while this forest, once established, may go on growing for an unknown number of thousands of years. The 800 or 1,000 years estimate from the growth of existing vegetation is a minimum which has no bearing whatever on the actual age of these mounds, and we might almost as well attempt to determine the time of the glacial epoch from the age of the pines or oaks which now grow on the moraines. The important thing for us, however, is that when North America was first settled by Europeans, the Indian tribes inhabiting it had no knowledge or tradition of any preceding race of higher civilization than themselves. Yet we find that such a race existed; that they must have been populous and have lived under some established government; while there are signs that they practiced agriculture largely, as indeed they must have done to have supported a population capable of executing such gigantic works in such vast profusion—for it is stated that the mounds and earthworks of various kinds in the state of Ohio alone amount to between eleven and twelve thousand. In their habits, customs, religion, and arts, they differed strikingly from all the Indian tribes; while their love of art and of geometric forms, and their capacity for executing the latter upon so gigantic a scale, render it probable that they were a really civilized people, although the form their civilization took may have been very different from that of later people subject to very different influences, and the inheritors of a longer series of ancestral civilization.

We have here, at all events, a striking

example of the transition, over an extensive country, from comparative civilization to comparative barbarism, the former having left to tradition, and hardly any trace of influence on the latter. As Mr. Mott well remarks:—Nothing can be more striking than the fact that Easter Island and North America both gave the same testimony as to the origin of the savage life found in them, although in all circumstances and surroundings the two cases are so different. If no stone monuments had been constructed in Easter Island, or mounds, containing a few relics saved from fire, in the United States, we might never have suspected the existence of these ancient peoples. He argues, therefore, that it is very easy for the records of an ancient nation's life entirely to perish, or to be hidden from observation. Even the arts of Nineveh and Babylon were unknown only a generation ago, and we have only just discovered the facts about the mound-builders of North America. But other parts of the American continent exhibit parallel phenomena. Recent investigations show that in Mexico, Central America, and Peru, the existing race of Indians has been preceded by a distinct and more civilized race. This is proved by the sculptures of the ruined cities of Central America, by the more ancient terra cottas and paintings of Mexico, and by the oldest portrait pottery of Peru. All alike show markedly non-Indian features, while they often closely resemble modern European types. Ancient crania, too, have been found in all these countries, presenting very different characters from those of any of the modern indigenous races of America.

There is one other striking example of a higher being succeeded by a lower degree of knowledge, which is in danger of being forgotten because it has been made the foundation of theories which seem wild and fantastic, and are probably in great part erroneous. I allude to the Great Pyramid of Egypt, whose form, dimensions, structure, and uses have recently been the subject of elaborate works by Prof. Piazzi Smyth. Now, the admitted facts about this pyramid are so interesting and so apposite to the subject we are considering, that I beg to recall them to your attention. Most of you are aware that this pyramid has been carefully explored and measured by successive Egyptologists, and the dimensions have lately become capable of more accurate determination owing to the discovery of some of the original casing-stones, and the clearing away of the earth from the corners of the foundation, showing the sockets in which the corner-stones fitted. Prof. Smyth devoted many months of work with the best instruments in order to fix the dimensions and angles of all accessible parts of the structure; and he has carefully determined these by a comparison of his own and all previous measures, the best of which agree pretty closely with each other. The results arrived at are:—1. That the pyramid is truly square, the sides being equal and the angles right angles. 2. That the four sockets on which the first stones of the corners rested are truly on the same level. 3. That the direction of the sides are accurately to the four cardinal points. 4. That the vertical height of the pyramid bears the same proportion to its circumference at the base, as the radius of a circle does to its circumference.

Now all these measures, angles, and levels are accurate, not as an ordinary surveyor or builder could make them, but to such a degree as requires the very best modern instruments and all the refinements of geodetical science to discover any error at all. In addition to this we have the wonderful perfection of the workmanship in the interior of the pyramid, the passages and chambers being lined with huge blocks of stone fitted with the utmost accuracy, while every part of the building exhibits the highest structural science. In all these respects this largest pyramid surpasses every other in Egypt. Yet it is universally admitted to be the oldest, and also the oldest historical building in the world. Now these admitted facts about the Great Pyramid are surely remarkable, and worthy of the deepest consideration. They are facts which, in the pregnant words of the late Sir John Herschel, "according to received theories ought not to happen," and which, he tells us, should therefore be kept ever present to our minds, since "they belong to the class of facts which serve as a clew to new discoveries."

According to modern theories, the higher civilization is ever a growth and an outcome from a preceding lower state; and it is inferred that this progress is visible to us throughout all history and in all the material records of human intellect. But here we have a building which marks the very dawn of history—which is the oldest authentic monument of man's genius and skill, and which, instead of being far inferior, is very much superior to all which followed it. Great men are the products of their age and country, and the designers and constructors of this wonderful monument could never have arisen among an unintellectual and half-barbarous people. So perfect a work implies many preceding less perfect works which have disappeared. It marks the culminating point of an ancient civilization, of the early stages of which we have no record whatever.

The three cases to which I have now adverted (and there are many others) seem to require for their satisfactory interpretation a somewhat different view of human progress from that which is now generally accepted. Taken in connection with the great intellectual power of the ancient Greeks—which Mr. Galton believes to have been far above that of the average of any modern nation—and the elevation, at once intellectual and moral, displayed in the writings of Confucius, Zoroaster, and the Vedas, they point to the conclusion that, while in material progress there has been a tolerably steady advance, man's intellectual and moral development reached almost its highest level in a very remote past. The lower, the more animal, but often the more energetic types, have, however, always been far the more numerous; hence such established societies as have here and there arisen under the guidance of higher minds have always been liable to be swept away by the incursions of barbarians. Thus in almost every part of the globe there have been a long succession of partial civilizations, each in turn succeeded by a period of barbarism; and this view seems supported by the occurrence of degraded types of skull along with such "as might have belonged to a philosopher"—at a time when the mammoth and the reindeer inhabited southern France. Nor need we fear that there is not time enough for the rise and decay of so many successive civilizations as this view would imply; for the opinion is now gaining ground among geologists that palœolitic men were really preglacial, and that the great gap—marked alike by a change of physical conditions, and of animal life—which in Europe always separates him from his neolithic successor, was caused by the coming on and passing away of the great ice age. If the views now advanced are correct, many, perhaps most, of our existing savages are the successors of higher races; and their arts, often showing a wonderful similarity in distant continents, may have been derived from a common source among more civilized peoples.

THE SHERMAN PUDDLING PROCESS.—After the numerous experiments made in England, with altogether negative results, we did not expect to hear more about this process, especially also, as at the meeting of the Société de l'Industrie Minerale, M. Euverte communicated the results of the experiments made with this process, and the conclusion which he arrived at was that it did not appear to have any influence on the quality of the steel, and was not worthy of further consideration by metallurgists. The president of the meeting, M. de Cizancourt, however, protested against these conclusions, declaring that at M. Verdié's Iron Works there had already been more than 1,200 tons of metal containing phosphorus treated by this process with complete success; and at the subsequent meeting of the society, M. E. Verdié read a communication in reply to the paper of M. Euverte, to the effect that the results obtained by using the Sherman process at the Firminy Iron Works proved that even, when the amount of phosphorus present was greater than at Terre-Noire, the steel produced was more carburetted, purer, contained less phosphorus, and was made at a lower price. M. Verdié admitted that the re-agents employed did not consist only of the 30 grammes iodide of potassium, but were alkaline salts in the proportion of two kilogs. per charge, the iodide included, which is, therefore, not exactly the same as specified in Sherman's patent.

TRANSMISSION OF POWER BY WIRE ROPES.*

By ALBERT W. STAHL, Cadet-Engineer, M. E., U. S. N.

I.

Section I.

INTRODUCTION.

It is a noteworthy historical fact, that economy in the generation of power in the motor, and economy in its utilization in the machine, have, in most countries, been far in advance of its economical transmission from the one to the other.

Ever since the steam engine became an established fact in the hands of Watt, inventors have been engaged in making improvements to render it still more efficient. The immense strides taken in advance may be well appreciated by even the most casual comparison of the engine of Watt's time, with one of the powerful and economical engines of the present day.

Not only have such ideas, as the expansion of steam, been developed to a remarkable extent, but even in the smallest details the watchful eye of the mechanic has ever been finding room for improvement.

In the course of invention, the principles upon which the steam engine has been made a practical success have been developed; and during the present century, the chief application of inventive genius has been turned in the direction of improvement in the combination of the parts of the engine itself. There has been no fundamental change in the conception of the necessary parts of the steam engine; but various modifications of the mechanism have been introduced, whereby the power has been economized, or the necessary friction of the parts has been lessened. Influenced by the same spirit which has characterized the scientific advance of this century; by the increasing necessity of more accurate methods; and forced by the industrial competition of the age to consider the importance of economy of time and energy, the improvers of the steam engine have seen that their inventions would be recognized as valuable, only as they attained the same results with increased simplicity of action, with less waste of power in the working of the mechanism, or with a less supply of fuel.

As the Englishman, Watt, in the last century, found the steam engine an imperfect and wasteful arrangement for utilizing only a small portion of the energy of the steam supplied to it, and by his invention of a separate condenser, and then by his method of making the engine double-acting, made it really a steam engine; so in this century the credit is largely due to Americans, such as Allen, Corliss and others, for improvements by which, in the engines known under their respective names, simplicity of construction, together with perfection of economy in working, have been secured.

While, in the department of steam engineering, as well as in the no less important domain of boiler-making, we are thus devoting all our energies to increasing the efficiency of the prime mover, a painful lack of care is manifest in the utilization of the power which we purchased so dearly. Obtaining only a small fraction of the theoretical power, it becomes us to husband it with the greatest care, and to allow it to do its allotted work with the least possible waste in the transmission from the prime mover to the machine.

Years ago there were excellent waterwheels, and by them were driven machines of surprising ingenuity, but the power was conveyed to the machines by means of cumbersome wooden shafts, upon which were wooden drums for the driving belts; gearing, too, made of wood; slow-moving, awkward contrivances for the purpose, and very wasteful of power. In Oliver Evans' "Millwright's Guide," which is recognized as the standard book of his time, we read of wooden shafts, wooden drums, and wooden gearing only.

At a later day, gear wheels were used to transmit the power from the motor to the shaft, while belts or bands were only used to transmit the power from the shafts to the individual machines.

* A graduating thesis at the Stevens Institute of Technology, Hoboken, N. J., June 30th, 1876.

The transmission of power to distances was accomplished by lines of shafting, either laid in ditches underground, or supported on columns high enough not to impede passage beneath the shafts. But even this method was seldom used, except in cases of necessity, owing to its immense first cost.

Although among the most efficient means of transmitting power to short distances, both belting and shafting have the disadvantage, that when the distance becomes great, the intermediate mechanism absorbs an important portion of the power by vibrations, friction, and resistances of every nature; and, for a distance of several hundred feet, we do not get, at one end of the transmission, more than an extremely small fraction of the power applied to the other.

In the case of a mere dead pull, as in working a pump, work is, and has long been, transmitted to great distances; as by the long lines of "draw-rods," used in mining regions to transmit the power of a water-wheel by means of a crank on its main axis, pulling, during half its revolution, against a heavy weight, and thus storing up energy for the return stroke, as the rods, on account of their flexibility, cannot be used to exert a pushing strain. Rotary motion, however, cannot be economically produced in this manner.

Another method, which has been much employed recently, is that known as hydraulic connection; and Armstrong has even perfected apparatus by which water pressure, thus transmitted through, perhaps, miles of pipe, may be converted into rotary motion.

Compressed air has also come largely into use, and there is no doubt that power may be transmitted to great distances by rarefied or compressed air, and may be converted into rotary motion at any desired point. But in the compression of air, heat is generated; and the latter being conducted rapidly away by the sides of the tube, the loss from this source alone becomes very serious. Another disadvantage, incident on both of the last two cases is that unless the area of the tubes is very large compared with the current flowing through them, the loss by friction rises to a large percentage of the power transmitted. The capital to be sunk in pipes, therefore, is very large, and both this expenditure and the waste of power increase directly with the distance. Such were some of the methods employed to transmit power to great distances, before the invention of transmission of power by wire ropes by the Brothers Hirn, of Mulhausen, Switzerland.* These gentlemen have stated the question of the transmission of power in the most general manner, *i. e.* independently of the intensity of the pressure to be transmitted, and of the distance to be passed over; and the solution which they have given to this grand problem is so simple, that the apparatus proposed seems, to the casual observer, to be little else than a more extended application of that commonplace "wrapping connector," the belt and pulley. The principle involved, however, is something entirely different.

Simplicity, always the fundamental characteristic of great inventions, rarely shows itself more clearly than in, as they are called, the telodynamic cables. To a person seeing them in operation, they seem the embodiment of simplicity; nevertheless, the Brothers Hirn have the undisputed honor of inventing them. To satisfy themselves on this point, the International Jury at the Paris Exposition in 1867, made a deep research, and examined the patent registers for many years back, but failed to find anything bearing the least resemblance to the telodynamic cables.

This method of transmitting power depends upon two principles in mechanics:

(1) The dynamic force is measured by the product of the force and the velocity with which it moves;

(2) In mechanical work, power may be exchanged for velocity, and velocity for power.

To illustrate, let us suppose a bar of iron, having a cross sectional area of one inch, to move endlong at the rate of two feet per second. Now, if the resistance overcome is say 5,000 pounds, work will be performed at the rate of 10,000 foot-pounds per second. Now, if we double the velocity of the bar, we will transmit twice the amount of work with the same strain, or the same work may be produced with only half the former strain,

* See "Notice sur la transmission telodynamique, par C. F. Hirn (Colmar, 1862)."

i. e. by a bar having an area of only half a square inch. In a similar manner, if we move the bar with the velocity employed in telodynamic transmission, viz., about eighty feet per second, then, while doing the same amount of work, the strain on the bar will be reduced from 5000 to 125 pounds, and the bar will only need a section of 1-40 square inch. To put an extreme illustration, we might conceive of a speed at which an iron wire, as fine as a human hair, would be able to transmit the same amount of work as the original one-inch bar.

By the application of these simple principles in Hirn's apparatus, the greater part of the force is first converted into velocity, and at the place where the power is required, the velocity is changed back into force.

Section II.

THE DRIVING WHEELS.

The construction of the apparatus is very simple. A tolerably large iron wheel, having a V shaped groove in its rim, is connected with the motor, and driven with a perimetral velocity of from sixty to one hundred feet.

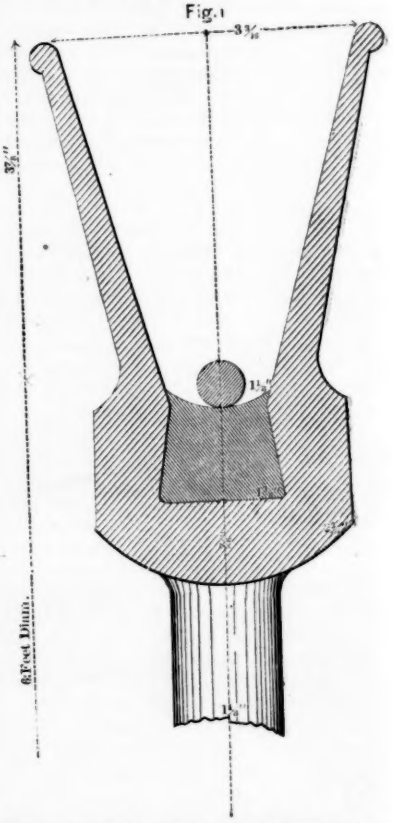
Round this wheel is passed a thin wire rope, which is led away to almost any reasonable distance (the limit being measurable by miles), where it passes over a similar wheel, and then returns as an endless band to the wheel whence it started.

The peripheries of the driving wheels may have an angular velocity as great as possible; the only limit in fact, being that the speed shall not be likely to destroy the wheels by centrifugal force. The speeds which have been actually employed in the examples to which I propose to refer, vary from 25 to 100 feet per second, at the circumference of the pulley.

The wheels themselves are made as light as is consistent with strength, not only for the sake of reducing the inertia of the moving mass, and the friction on the axis to a minimum, but for the equally important object of diminishing the resistance of the air. It can hardly be doubted that abandoning spokes entirely, and making the pulley a plain disc, would improve essentially the performance could such discs be made at once strong enough to fulfill the required function, and light enough not materially to increase the friction.

The wheels have been made of cast iron and steel, and beside their lightness, have but one peculiarity of construction, and that is a highly important one. At the bottom of the acute V shaped groove, going around the circumference, a little trough is formed in which the filling is placed, as shown in Fig. 1.

Fig. 1

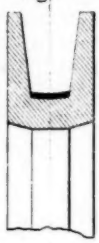


The materials used for this filling are many in number, and will be discussed further on. The rope should always run on a filling of some kind, and not directly on the iron, which would quickly wear it out.

The rope is not tightly stretched over the wheels, but, to all appearances, hangs loosely on the same. But the rope does not slip, as the tension caused by its own weight presses it hard against the

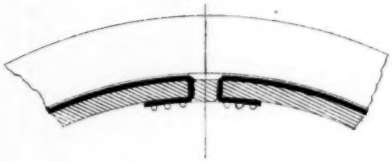
rim of the wheels, if the latter are of proper size. The body of the driving wheel differs very little from that of a belt pulley; and it can always be proportioned as a belt pulley having to transmit the same power with the same velocity. The peculiarity of the wheel lies

Fig. 2



in its rim, as previously explained. In the early experiments on the transmission of power in this manner, the rims were made of wood with a leather belt as filling, (see Figs. 2 and 3.)

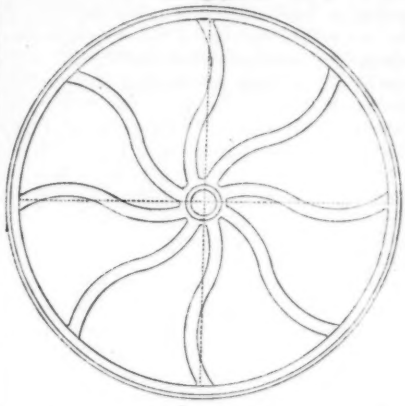
Fig. 3



This kind of rim has now gone entirely out of use, and has been replaced by a wheel cast solid with an iron rim, whose edges, in a a single grooved wheel, are inclined at about twenty-five degrees from the vertical, (Figs. 1 and 4). In some instances where the ropes were exposed to a high side wind, the slope has been made as great as 45°, but this a very unusual case.

The angle of 30°, if used in a double grooved wheel, would give an extremely heavy central rib, on which account the sides of the latter are usually made steeper, viz. about 15° from the vertical wheels from about nine feet in diameter up are usually cast in halves and afterward fastened together on the shaft. In order that the centrifugal force may not become dangerous, the perimetral velocity should not exceed 90 to 100 feet per seeond. Velocities up to 90 feet have

Fig. 4



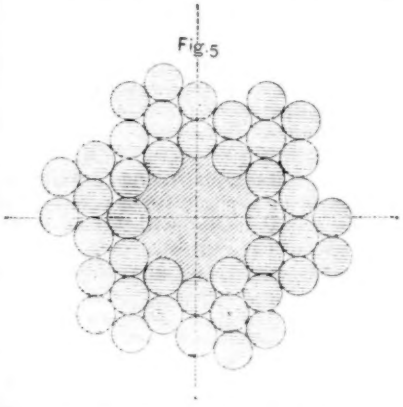
been frequently used. without any prejudical results whatever.

Section III.

THE DRIVING ROPES.

The driving rope usually employed in this country consists of six strands, with seven wires to each strand (see Fig. 5).

Fig. 5



The strands are spun around a hempen center or core, thus obtaining the necessary flexibility.

When wire rope is referred to in this thesis without special qualification, it is to be understood to mean Messrs. J. A. Roebling's Sons' 42 wired round iron wire rope. The diameter of this kind of rope is nine times the diameter of the wire of which it is composed. That is to say, if D = the diameter of the rope,

and d = diameter of the wire, then D = 9d.

The following table gives the weight, strength, etc., of Messrs. Roebling's

42 WIRED ROPE:

Trade Number.	Diameter in inches.	Circumference in inches.	Weight per foot in pounds.	Ultimate strength in pounds.	Proper tension in pounds.	Price per foot in cents.
25	1/4	3/4	.125	2060	515	5
24	9/32	1	.162	2760	690	7
23	5/16	1 1/8	.189	3300	825	8
22	11/32	1 1/4	.23	4260	1065	9
21	3/8	1 3/8	.3	5660	1415	10
20	13/32	1 1/2	.41	8200	2050	12
19	7/16	1 5/8	.5	11600	2900	14
18	15/32	2 1/4	.686	15200	3800	17
17	1/2	2 3/8	.86	17600	4400	20
16	17/32	2 1/2	1.12	24600	6150	25
15	1	3	1.43	32000	8000	32

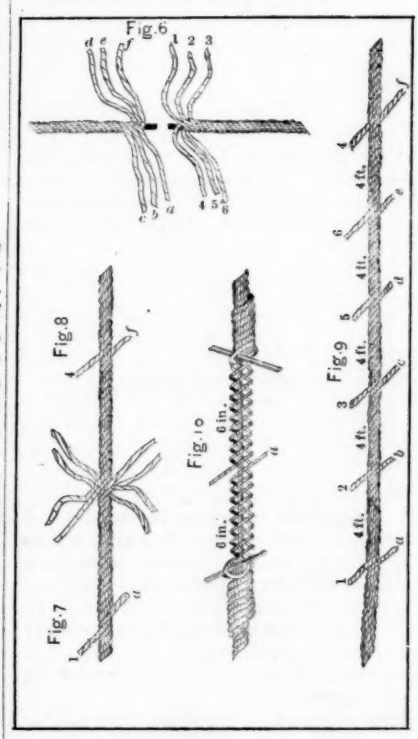
In the manufacture of the rope, the quality of the iron wire must be inspected very carefully, in order to insure durability. The best wire is that made of Swedish iron, uniting great toughness with great tensile strength. Steel wire has not been found well adapted for this work. Particular attention must be paid to getting each wire as long as possible, so as to lessen the number of joints.

In splicing a wire rope, the greatest care must be taken to leave no projecting ends or thick parts in the rope. On this subject, I can do no better than give Messrs. Roebling's directions for making a long splice in an endless running rope of half inch diameter.*

Tools required: One pair of nippers, for cutting off ends of strands; a pair of pliers, to pull through and straighten ends of strands; a point, to open strands; a knife, for cutting the core; and two rope nippers, with sticks to untwist the rope; also a wooden mallet.

First.—Have the two ends taut, with block and fall, until they overlap each other about twenty feet. Next, open the strands of both ends of the rope for a distance of ten feet each; cut off both hemp cores as closely as possible (see Fig. 6), and then bring the open bunches of strands face to face, so that the opposite strands interlock regularly with each other.

Secondly.—Unlay any strand, a, and follow up with the strand 1 of the other end, laying it tightly into the open groove left upon unwinding a, and making the twist of the strand agree exactly with the lay of the open groove, until all but about six inches of 1 are laid in, and a has become twenty feet long. Next cut off a within six inches of the rope (see Fig. 7), leaving two short ends, which must be tied temporarily.



Thirdly.—Unlay a strand, 4, of the opposite end, and follow up with the strand, f, laying it into the open groove, as before, and treating it precisely as in the first case (see Fig. 8). Next, pursue the same course with b and 2, stopping, however, within four feet of the first set; next with e and 5; also with c, 3 and d, 4. We now have the strands all laid into each other's places, with the respect-

* See "Transmission of Power by Wire Ropes," by W. A. Roebling, C. E.

ive ends passing each other at points four feet apart, as shown in Fig. 9.

Fourthly.—These ends must now be secured and disposed of, without increasing the diameter of the rope, in the following manner: Nipper two rope-slings around the wire rope, say six inches on each side of the crossing point of two strands. Insert a stick through the loop and twist them in opposite directions, thus opening the lay of the rope (see Fig. 10). Now cut out the core for six inches on the left and stick the end of 1 under *a*, into the place occupied by the core. Next, cut out the core in the same way on the right, and stick the end of *a* in the place of the core. The ends of the strands must be straightened before they are stuck in.

Now loosen the rope nipper and let the wire rope close. Any slight inequality can be taken out by pounding the rope with a wooden mallet.

Next, shift the rope nippers, and repeat the operations at the other five places.

After the rope has run for a day, the locality of the splice can be no longer detected. There are no ends turned under or sticking out, as in ordinary splices, and the rope is not increased in size, nor appreciably weakened in strength.

I have dwelt so minutely on the process of splicing, because practical experience has demonstrated that a man who can splice a wire rope well, is something of a rarity. Some of the best ship-riggers are utterly non-plussed when a wire rope is presented to them to be spliced; and the splice they produce is usually half again as thick as the rope, and utterly useless for the intended purpose.

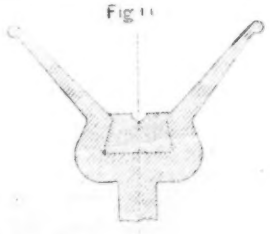
When a rope has been well spliced and kept running, its average life is about three years.

Up to this point, I have been speaking of the common wire ropes, as generally made and used for the purpose of transmitting power, viz. wire ropes with hemp centers, and also those with wire centers. The latter have not given satisfactory results, as they wear out very rapidly. The only advantages to be gained by using a wire center rather than one of hemp, are that the same amount of force may be transmitted with a relatively smaller rope, and that the rope itself stretches less. This latter difficulty can be almost entirely obviated, as will be explained further on; and as the ropes with hemp centers are much more durable, they are now the only ones used. Another disadvantage found in the use of ropes with wire centers, is that the splice must be made nearly twice as long as when hemp is used for the center. This must be done to prevent the two ends of the rope from slipping out, as the co-efficient of friction is not so great between iron and iron, as between iron and hemp.

As in splicing, the wire center is cut off at the splice, and not spliced in, it is free to move in the rope in the direction of least resistance. It consequently happens that the wire center frequently protrudes through the strands of the rope. This may be partly remedied by serving with chord through the center and the outside wires, thus fastening them in their proper relative positions. In a short time, however, the center will again project; we are then compelled to cut off the projecting end, and repeat the operation of serving with cord; which does not by any means improve the durability of the rope. The principal difficulty, the excessive wear of the outer wires, is common to both kinds of ropes. This wear is caused chiefly by the friction of the wire on the sides of the wheel-groove, when the rope, for any reason, runs unsteadily and swings against the sides of the groove. The ropes get flat in places and finally the wires break.

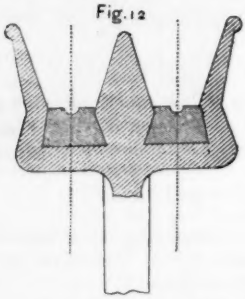
We may keep a transmission in as thorough repair as we will, but we can not prevent, that at times there will be more or less oscillating and swinging of the ropes against the wheel-rim, resulting in the wear above referred to. This evil may be greatly obviated by making

Fig 11



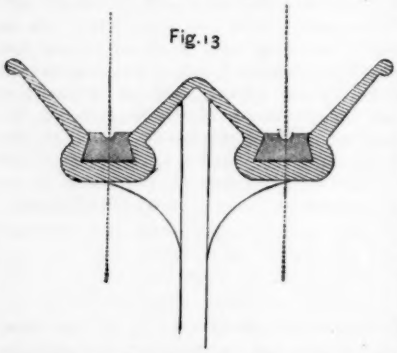
the section of the wheel-rim more of the form shown in Fig. 11. But this is attended with several disadvantages, particularly in the case of double-grooved wheels (compare Figs. 12 and 13).

Fig. 12



This would increase the difficulty and expense of making the wheels, and would have the great disadvantage that the distance between the ropes would be greater, resulting in a considerable side pressure on the bearings of the shafts.

Fig. 13



To prevent the wear of the wires, and thus to make the ropes more durable, has been the object of several inventions; all of which were attempts at surrounding the wires with a flexible and durable covering, protecting the wires, and at the same time not increasing the difficulties of splicing. It was also thought, that if this could be made a practical success, the filling in the wheels might be entirely dispensed with. Instead of the rope running on the soft filling of the wheel, the soft envelop of the rope might run directly on the cast iron rim. Nearly all the experiments in this direction have failed, and it is only very recently that the firm of Martin Stein & Co., Mulhausen, Switzerland, have solved this question. They have for some time been making ropes in which coarse cotton yarn was spun about the separate wires, the latter being then spun into rope. In this way they obtained a soft body between the separate wires, and also a soft envelop for the whole rope, which, when saturated with a special resinous compound, is said to be very durable. This kind of covered rope stretches much less than the common rope. Comparisons made, indicate a stretch of only 06 per cent. It also seems less subject to the variation of weather, being partly protected against sun and rain by the covering. For the same reason, rusting is not likely to occur. If, in connection with these covered ropes, we also employ wheels with leather filling, the adhesive force on the pulleys becomes much greater than in the ordinary ropes; thus allowing the transmission to be worked with much less tension in the ropes. If we desire to get the same cross-sectional area of metal in these ropes as in the common ones, the size of rope required will, of course, be considerably greater, but the rope itself will be much more flexible. In this case, we can, without any harm resulting therefrom, introduce covered wire centres instead of using hemp.

Messrs. Stein & Co. have also been experimenting with hemp as a covering, instead of the expensive cotton yarn, but their experiments are of too recent date to be discussed here.

The price of covered wire ropes is, of course, greater than that of the common ropes. But if they are as durable as the manufacturers claim, *i. e.*, if they may be expected to last about ten years, it is, of course, more true economy to use the more expensive rope. By using these covered ropes, previously well stretched, we may doubtless avoid the various difficulties which have opposed and prevented the more general introduction of the transmission of power by wire-ropes.

Section IV.

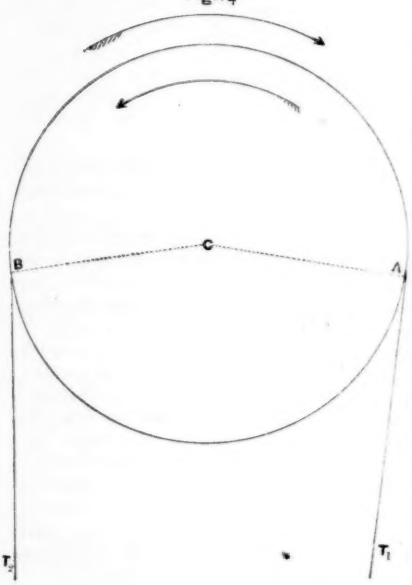
The Tension on the Rope.

I shall first present the demonstration of the friction of a simple band, as given in Rankine's "Millwork and Machinery."

A flexible band may be used either to exert an effort or a resistance upon a drum or pulley. In either case, the tangential force, whether effort or resistance, exerted between the band and the pulley, is their mutual friction, caused by and proportional to the normal pressure between them.

In Fig. 14, let C be the axis of a pulley AB, round an arc of which there is wrapped a flexible band, $TABT_2$; let

Fig. 14



the outer arrow represent the direction in which the band slides, or tends to slide, relatively to the pulley, and the inner arrow the direction in which the pulley slides, or tends to slide, relatively to the band. Let T_1, be the tension of the free part of the band at that side *towards* which it tends to draw the pulley, or *from* which the pulley tends to draw it; T_2, the tension of the free part at the other side; T, the tension of the band at any intermediate point of its arc of contact with the pulley; θ, the ratio of the length of that arc to the radius of the pulley; $d\theta$, the ratio of an indefinitely small element of that arc to the radius; $R = T_1 - T_2$ = the total friction between the band and the pulley; dR, the elementary portion of the friction, due to the elementary arc $d\theta$; f, the coefficient of friction between the materials of the band and pulley. Then it is known that the normal pressure at the elementary arc $d\theta$ is $T d\theta$; T being the mean tension of the band at that elementary arc; consequently the friction on that arc is

$$dR = f T\, d\theta.$$

Now, that friction is also the difference between the tensions of the band at the two ends of the elementary arc; or

$$dT = dR = f T\, d\theta;$$

which equation being integrated throughout the entire arc of contact, gives the following formulae:

$$\left.\begin{aligned} &\text{hyp. log. } \frac{T_1}{T_2} = f\theta\,;\quad T_1 \div T_2 = e^{f\theta} \\ &R_1 = T - T_2 = T_1(1 - e^{-f\theta}) = T_2(e^{f\theta} - 1) \end{aligned}\right\} \quad (1)$$

When a belt connects a pair of pulleys at rest, the tensions of its two sides are equal; and when the pulleys are set in motion, so that one of them drives the other by means of the band, it is found that the advancing side of the belt is exactly as much tightened as the returning side is slackened, so that the mean tension remains unchanged. The ratio which it bears to the force, R, to be transmitted, is given by this formula:

$$\frac{T_1 + T_2}{2R} = \frac{e^{f\theta} + 1}{2(e^{f\theta} - 1)} \quad . \quad . \quad . \quad (2)$$

If the arc of contact between the band and the pulley, expressed in fractions of a turn, be denoted by n, then

$$\theta = 2\pi n\,;\quad e^{f\theta} = 10^{2.7288 f n} \quad . \quad (3)$$

that is to say, $e^{f\theta}$ is the antilogarithm, or natural number, corresponding to the common logarithm $2.7288 f n$.

The value of the coefficient of friction, f, depends on the state and material of the rubbing surfaces. This coefficient is about 0.25 when wire rope is used running on leather or gutta percha. In wire rope transmission $n = \frac{1}{2}$; inserting this value, and also the value of f, in equation (2), we get:

$\frac{T_1}{T_2}=2.188$; $\frac{T_1}{R}=1.84$; $\frac{T_1+T_2}{2R}=1.34$.

In ordinary practice, it is usual to assume

$$T_2=R;\ T_1=2R;\ \frac{T_1+T_2}{2R}=1.5$$

This has been done in the calculations in this thesis. Therefore, if with a wire rope we wish to transmit a certain force P, we must proportion the transverse dimensions of the rope to bear the maximum strain that will come on it. This maximum strain will come on the driving side of the rope and be equal to twice the force transmitted, *i. e.*, equal 2 P.

In all the following calculations, the strength of the hemp core is left entirely out of consideration, as it is only used for the purpose of securing flexibility, and not for strength. If it is an error to leave this out, it is only a slight one, and is on the safe side at that.

Let P=force to be transmittted.

a=total cross-sectional area of wires in rope in square inches.

t=tension in pounds per square inch of cross-sectional area of wires.

Then $ta=2P$; and $a=\frac{2P}{t}$.

n=the number of wires in the rope =42.

d=diameter of each wire; then

$$n\frac{\pi}{4}d^2=a=\frac{2P}{t}.$$

H.P=number of horse-power to be transmitted.

R=radius of wheel in feet.

N=number of revolutions per minute.

Then, by the proper substitutions, we get:

$$n\frac{\pi}{4}d^2=\frac{2}{t}\times\frac{33000\text{ H. P.}}{2\pi RN}=\frac{33000\text{ H. P.}}{t\pi RN} \quad (4)$$

$$d^2=\frac{132000\text{ H. P.}}{tn\pi^2 RN} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

After substituting for n its value, 42, we get:

$$d=\sqrt{\frac{31.85\text{ H. P.}}{tRN}} \quad . \quad . \quad . \quad (6)$$

To find the value of d from the preceding equations, we must know at the very outset, what is the proper tension to use in the ropes. The tension in the rope is composed of three parts; viz.: 1st, the tension necessary to transmit the required amount of power with the velocity of the wheel; 2d, the tension produced by the bending of the rope around the wheel, causing the outer fibres of each wire to be extended and strained; 3rd, the tension caused by the centrifugal force.

This centrifugal tension, though never amounting to much in ordinary practice, becomes somewhat of an item when a velocity of nearly a mile per minute is employed. It is the sum of these tensions which the rope is called upon to resist.

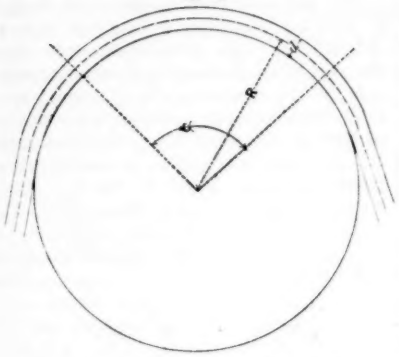
Determining the proper tension is, of course, equivalent to fixing on a factor of safety. Rankine states that three and a half is a good factor for steady work. Although this may at first sight, seem rather low, it must be borne in mind that the process of wire drawing is a process of testing, so that we are certain of having only the best materials. We may, therefore, safely work with this factor, but for the sake of durability, a somewhat higher factor seems advisable. In this thesis, four (4) has been taken as the factor of safety. To find the tension available for the transmission of power, we must evidently get the difference between the total tension and the sum of the tensions produced by bending and by centrifugal force.

We will, therefore, pass at once to the consideration of the tension caused in the rope, by bending the same around the wheels.

In Figure 15, let R= radius of the wheel, d= diameter of a single wire, and E= modulus of elasticity of wire. Now it is apparent that when the rope is compelled to bend to the curve of the wheel, the outer fibres of each wire will be extended and the inner ones compressed, while the center (the neutral axis) will remain unchanged in length. As the strain varies with the size of the wheel, becoming greater as the wheel is made smaller, and *vice versa* it is of importance to determine what should be the relation between the diameters of the wire and of the wheel. In ordinary

practice this ratio ranges between 1,000 and 2,500.

Fig. 15



If in Fig. 15, we consider the arc which subtends the angle α, the length of the neutral axis will be $\frac{\pi}{180} R \alpha$. But the outermost fiber subtends the same angle with a radius $R + \frac{d}{2}$; therefore, its length must be $\frac{\pi}{180}\left(R+\frac{d}{2}\right)\alpha$. The amount by which the outer wire has been extended is evidently the difference between these two lengths; *i. e.*, the extension

$$\lambda = \frac{\pi}{180}\left(R+\frac{d}{2}-R\right)\alpha = \frac{\pi}{180}\cdot\frac{d}{2}\alpha \quad (7)$$

If t_0 = tension produced in the rope by bending, then, from the definition of the modulus of elasticity, "the quotient obtained by dividing the force which produces the displacement by the amount of the extension," we get

$$E = \frac{t_0 \frac{\pi}{180} R\alpha}{\frac{\pi}{180}\frac{d}{2}\alpha} = \frac{t_0 R}{\frac{d}{2}} = \frac{2 t_0 R}{d} \quad (8)$$

$$t_0 = \frac{E d}{2 R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$\frac{R}{d} = \frac{E}{2 t_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

From these equations the tension may be determined. For the elasticity of iron wire we may take the mean of various experiments; viz.: 28,000,000 lbs. Substituting this value of E_1 and also introducing for d its value $\frac{D}{9}$, we have for the tension per square inch caused by bending

$$t_0 = 28000000\frac{D}{18R} = 1555555\frac{D}{R} \quad . \quad . \quad (11)$$

Substituting in equation (11) some of the probable values of the ratio $\frac{D}{R}$, we get the following table:

$\frac{R}{D}$	t_0	$\frac{R}{D}$	t_0
40	38888	120	12963
45	34570	130	11965
50	31111	140	11111
55	28282	150	10730
60	25925	160	9722
65	23930	170	9150
70	22222	180	8642
75	20740	190	8187
80	19444	200	7777
85	18300	210	7407
90	17284	220	7161
95	16374	230	6763
100	15555	240	6481
110	14141	250	6222

This table is somewhat interesting, as it shows clearly the cause of the rapid wear of the ropes when running on small pulleys. When the ratio $\frac{R}{D}$ is large, the tension varies but slightly, with small changes in this ratio; while if the latter is below about 100, the tension increases at a much faster rate than $\frac{R}{D}$ decreases. On the one hand, as the ratio $\frac{R}{D}$ decreases, the wheels become smaller and less expensive; but, on the other hand, we get so great a strain on the ropes that they quickly wear out. We must, therefore, seek to find a point at which the combined resultant economy may be as great as possible. This will be considered further on.

We will now take up the discussion of the centrifugal tension, using the diagram in Fig. 15.

Let R = radius of wheel in feet.

w = weight of the rope per running foot.

v = velocity of the rope in feet per second.

Then the centrifugal force $= \frac{m v^2}{R} = \frac{w}{g} \cdot \frac{v^2}{R}$

But the tension in an arc pressed normally by any force p is pR; consequently the *centrifugal tension*

$$t_2 = \frac{w}{g} \cdot \frac{v^2 R}{R} = .03106\, w v^2 \quad . \quad . \quad (12)$$

If we wish to express the velocity differently, we may write, when N = number of revolutions per second, $v = 2\pi R N$, $v^2 = 4\pi^2 R^2 N^2$; introducing this value of v^2, we have

$$t_2 = 1.226\, R^2 N^2 w \quad . \quad . \quad . \quad (13)$$

While the rope is passing around the wheel, it is subjected to a tension T, which is equal to the sum of these three separate tensions. But in any given case, we may evidently vary the component tensions at pleasure, provided we keep the total tension T constant.

We have previously (equations (5) and (6)) determined the diameter of the wires in terms of the tension t. But we now wish to introduce the total tension T, into this formula. Bearing in mind that $t = T - t_0 - t_2$, and multiplying equation (5) by the value of d^2 in equation (10), we get

$$d^2 = \frac{132000}{\pi^2 n E} \cdot \frac{2 t_0}{T - t_0 - t_2} \times \frac{H P}{N} = \frac{264000\, H.P.}{\pi^2 n E N} \times \frac{t_0}{t} \quad . \quad . \quad (14)$$

Having now obtained an equation introducing the ratio $\frac{t_0}{t}$, we must know how this is to be determined, i.e., what conditions control the magnitude of t_0 and t with respect to T.

(In all the following calculations, the centrifugal tension t_2 is not taken into consideration, as it only amounts to 250 pounds, even in an extreme case. This is a small quantity compared with the other tensions on the rope, and would lead to a needless complication of formulæ.) These conditions are two in number; 1st, the size of wheel that may conveniently be employed; 2nd, the resulting deflection or sag in the ropes, the latter being again subject to various conditions, such as the available height, etc.

We will now pass to the consideration of the 1st condition; viz.: the size of the wheels. As previously remarked, the value of R varies immensely with changes of t and t_0. The diameter of the wheel, however, is *always* very large, so that it becomes interesting to know under what conditions it assumes its smallest value. The first step is to obtain a perfectly general formula for R. This is done by multiplying equation (14) by the cube of equation (10) which gives as its result

$$R^3 = \frac{264000 H.P.}{\pi^2 n N} \cdot \frac{t_0 E}{8 t_0^2 (T - t_0^2)} \quad . \quad . \quad (15)$$

Differentiating this equation, we get

$$3 R^2 d R = \left(\frac{264000}{8 \pi^2 n N} \frac{H.P \times E}{} \right) (2 T t_0 - 3 t_0^2) d t_0$$

To find the conditions under which R will assume its minimum value, we must place the first differential coefficient equal to zero. Doing this, we get, after transposing and reducing

$$2 T t_0 = 3 t_0^2 \quad \therefore \quad t_0 = \tfrac{2}{3} T \quad . \quad . \quad . \quad . \quad (16)$$

$$t_0 = \tfrac{1}{2} t \quad . \quad . \quad . \quad . \quad (17)$$

This relation, being independent of the number of wires and of the shape of the rope, will of course hold good for a rope of any size and of any shape of cross-section. This shows the adaptability of this last formula to ropes of flat or rectangular cross-section, which have been used to a limited extent for transmitting power. From this formula, we see that in the case most favorable to small size of wheels, the tension caused by bending is twice as great as the *direct* tensional strain. The minimum value of R is, however, rarely used in practice, for a reason which will be shown presently. It may, however, be remarked here, that with a small working tension t, the deflection or sag of the rope is greater than that with an increased tension; so that in determining the ratio $\frac{t_0}{t}$ we must take into consideration the available height of the wheels above the ground. This point will be considered in the next section.

IRRIGATION IN CALIFORNIA.

By FRANK CARPENTER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

ONCE a board of honorable, learned, and impartial commissioners* reported that, with a proper system of irrigation, the great Valley of California would in twenty years become the granary of the world. With irrigation, they say, these plains will yield annually thirty bushels of wheat to the acre. Among their statistics they relate how two crops of barley, each forty bushels to the acre, were grown and harvested in the San Joaquin Valley in 245 consecutive days. Such are the favorable conditions of climate and soil that, with irrigation, they predict a probable average of two crops per year. As it is, without irrigation, an average of only two crops in five seasons is realized in the southern part of the valley, and times of famine, which result in the wholesale starvation of stock, are sometimes known. In conclusion, the commissioners report that the Great Valley of California is admirably adapted for irrigation; that the average yearly rainfall over this basin is sufficient to insure good crops annually; that the rainfall in different years is variable, and seasons of drought alternate with seasons of great floods; and that, with a proper system of controlling the waters of precipitation and doling them out to the cultivated fields when needed, regular crops will be assured.

Of the three home questions of vital importance to the people of that great State and little nation, California, the first, as this preface shows, is irrigation, and upon this first the other two hinge more or less directly. With irrigation will come an amicable solution of the second of these home questions, that of Chinese labor, for when the Caucasian freeholders shall become the keepers of the world's granary they will need very many toilers in the field and barn, more indeed than the nominal tide of immigration will introduce for twenty years to come. In overstocked China, the people have long ago learned economical ways of agriculture and the secret of securing great returns of produce from small areas of land, and, coming hither, they will bring with them those habits of frugality and thrift which are the basis of prosperity in the nation and happiness on the hearth, but which the Western land-holders, with farms as large as dukedoms, are inclined to despise. Four acres of land adapted to tillage, by irrigation, will yield as much revenue as four hundred acres of the scant and stunted pasturage now afforded. Therefore, with irrigation become general, the great West will afford homes and refuge to the surplus of all humanity for long to come. Except the mountainous grazing districts of Colorada and Arizona, and the high and forbidden regions around the Black Hills, there are now remaining but few acres of public lands that will, without artificial watering, yield the settler means of life. When these are pre-empted, as they soon will be, our broad domain of desert must be utilized, not as by the shiftless Arab, but as by the industrious Mormon, who has demonstrated that even the sage-brush land, which has hitherto been wronged with the stigma of utter worthlessness, has its virtues of good soil and possibilities of fruitfulness. The alkali flat may be worthless, but the sage-brush barren is not; the presence of this savory herbage is evidence, *prima facie*, that other and better things will grow there.

The great Valley of California is that interior basin at whose bottom lies the lakes of Kern and Tulare. Its available land is equal in area to half of the State of Ohio. It is a lake country, but far different from the lake countries of England, Switzerland, and New York. There is no beauty here, only the slope of low foot-hills subsiding into the plains, the plains running down to the damp bottom-lands, and the marsh sinking into the lake, in whose fringes of tule the water-fowls are at home. By day the sun is hot over these lakes,

*See "Report of the Board of Commissioners on the Irrigation of the San Joaquin, Tulare, and Sacramento Rivers of California; by Lieut. Col. S. B. Alexander and Major George H. Mendell, Corps of Engineers, U. S. A., and Professor George Davidson, U. S. Coast Survey."

breeding malaria, and at night the mosquito rides upon the fog. For this sad state of affairs irrigation is the proposed remedy.

The valley is divided into swamp land, which is too wet for cultivation, and the foot-hills and plains, which are too dry. So it is not the absence of water that retards the settlement and tillage of this vast tract, but its unequal distribution. The body of the water comes from the circumjacent mountains in the rainy season of the year. It rushes across the plains in torrents, fills the lake beds to repletion, and then stagnates and breeds fever during the dry summer. The retention of the water of these cataclysms and its storage upon high land, there to await gradual distribution over the plains and absorption by them, would result in the drying up and reclamation of the marshes, and thus the whole of the valley would become habitable.

But, in the case of the larger streams at least, the establishment of these reservoirs is too vast in nature and too broad in results to be entrusted to individual enterprise, or to any company of individuals less unselfish than the State at large. In irrigation, as elsewhere, the history of chartered companies is too often one of monopoly, forfeited promise, bribery in securing their commission, and subterfuge in fulfilling its requirements. Speculators band together in an incorporated company. They receive a grant of land for digging some canal of magniloquent title. By way of throwing a sop to Cerberus and satisfying the letter of the law, they plow a furrow or two along the proposed route of their public works. Then they disband and divide their subsidy. Or, accomplishing their work, they stand as middlemen between the farmer and the farmer's best friend, the rain, and sell dearly that boon which Heaven intended freely for just and unjust alike. Let the inhabitants of the city of New York fancy that the Croton Aqueduct is a broad river of water instead of a conduit of masonry; that every faucet in their houses has a discharge equal to the flow of an irrigating moat; and that their dependence upon this supply is a matter of prosperity or famine. Then let them suppose that the hands of some one, two, or three of the "kings" and "princes" of that city hold the gates of this main, and they can readily imagine the pitiable condition of the yeomen of the West, if they fall into the hands of the speculators.

The project is too vast to be confided to individuals seeking self-interest. Should the waters of the Sierra Nevada Mountains be leased to a little cabal of capitalists, it will not be long before the shrewdest man of this junto will be preeminent above his fellows; our country will be responsible for the production of another monstrosity, and we shall have our irrigation kings, as we now have bonanza kings, and railroad kings, which phenomenon, in a land which pretends to be averse to the kingly power, will not be consistent. On the other hand, should the rivers be farmed out, one to each company, there would be room for endless conflict, infringement, and litigation; two railways may intersect without jealousy on the part of their owners, but two irrigating ditches, never.

Now, how shall this thing be done? The Board of Commissioners, on account of limited time and means, could do no more than to hint vaguely of some manner of storage in winter and disbursement in summer; the writer begs leave to supplement their report by observations of his own. By way of illustration, let us take the Kern River, one of the principal affluents of this valley, which debouches into the southern portion through a narrow defile in the mountains, which rise some thousands of feet above the floor of the stream. Through these the water has cut a channel so narrow and impassable that there is not room for human travel between the river and its precipitous bluffs, and the stage-road runs perforce by a costly and laborious route high up among the hills. Beyond this cañon is the basin which shall serve as a reservoir. Just above, at the confluence of the forks of the Kern River, there is a valley, some forty or fifty square miles in extent, dyked in on every side by the mountains and their outlying spurs. As a site for a dam this spot is most admirable, and would make an engineer fall into estimates forthwith. Indeed, the body of this weir is already there; it is composed of the mountains themselves, and all that remains for the engineer to do is to

wall up the waste-gate of the cañon. If this one little outlet were closed, here would be a cistern with capacity enough to accommodate the gathered product of a thousand rainstorms. True, the back-water would drown out the little villages of Weldon and Kernville, and would flood the mines there; but *n'importe*, grain is better than gold, and this is a project for filling the world's granary.

This would be a prodigious piece of engineering. Such a river, swollen by freshets, is a force before which any ordinary wall of masonry would yield. For this and other reasons it might be unwise to undertake it without previous experiment on a more modest scale. After all, the smaller streams, which come down to the plains at regular and short intervals, can be more profitably utilized than the rivers, which are so large as to be unmanageable and so far between that the conveyance of the water to those fields which lie remote from the source of supply, is a work of great expense. Indeed, this is one of the principal arguments against the wholesale use of a large river, which is to be distributed over a great area. Since the water must be carried by gravitation down a constant and almost imperceptible gradient, the ditches must either wind in and out among the escaloping foot-hills, and around the heads of the valleys, often making many miles of detour in order to accomplish one mile of advance, or else, if the canal be projected in a direct line, frequent aqueduct bridges are necessary. Therefore, it would be well to reserve the four rivers, Sacramento, San Joaquin, Tulare, and Kern, for a few years, and as a last resort, to be used only under the lessons of fullest experiment.

Take, for instance, a creek which has ten miles of route through the mountains, with a proportional breadth of water-shed on either side. This would not be too cumbersome to be managed by a simple individual of means, or, at most, by a co-operative company. As an inventor makes and exhibits a model of the machine which he will afterwards develop to colossal size, so let some party prove, in miniature, the feasibility of irrigation by mountain reservoirs; in making this experiment such person or persons would be doing the world a service, and it would not be rash to promise them handsome returns of pecuniary profit as well.

Let there be taken as a field for this venture, the San Fernando Plain, a basin twelve by twenty miles in expanse, which lies south of the Great Valley. It is now a dry and unprofitable pasturage for sheep, whose frequent dead bodies testify of the insufficiency of their feed, but, with its conformation of gentle slopes, it is admirably adapted for irrigation and cultivation, and, were irrigation possible, this would be a most beautiful realm for a colony. In a dot of green oases on this plain are the gardens of the San Fernando Mission, established here by the Jesuits well-nigh a century ago. In these are tropical fruits and flowers in the rankest profusion and exuberance of growth. There are giant trees of olive and palm, overshadowing an undergrowth of fig and pomegranate, lofty and dense thickets of prickly pear, and tangled meshes of grapevine, while without the walls there is a strip of bottom-land with patches of melons and fields of barley. Again, at the mouth of a cañon not far away we found a squatter's shanty. Two years before, entrapping the stream with a ditch, he had led it away to the field which he had fenced from the sage-brush, growing tall and scraggy around. Eighteen months ago he had planted this orchard. Now the trees were laden so that their tender boughs were in peril. Never before had we seen such abundance of fruit or such precocity in the bearing of it. And yet without the fence was that emblem of desolation, the sage-brush, from which this spot had been reclaimed, barely two years since.

These instances are given as vouchers for the virtues of this land's climate and soil, developed when assisted by irrigation. Although, on account of the narrowness of the belt of water-shed surrounding it, it may never be possible to water the entirety of the San Fernando Plain, yet, with a large portion of it, irrigation is not only possible, but easy. Opening into its eastern border is the Pecoima Cañon, which, at its mouth, is a narrow cleft in the rock, and, at its head, is a broad and spacious sinus. Indeed, this formation, a bowl in the heart of the mountains with an opening which

is a fissure, seems to be general throughout this country. If it be true that nature has provided a cure for every one of her defects, then are these opportunities for reservoirs her remedy for the parched plains which lie adjacent, and, having given these hints, she artlessly expects man to do the rest. In the Pecoima Cañon this water gap is so narrow, the walls are so high and perpendicular, and the rock on the mountains overhead is so abundant that it would be a matter of trifling expense to block the cañon with a dam. Yet I daresay that this idea has never once occurred to those people, dons and padres, who have lived so long in this land, and of whom, except some occasional hardy hunter, not one has ever gone farther than to peer into the mouth of this fastness.

It is hard to imagine a finer property than this mountain tract, and a goodly portion of the San Fernando Plains would make. In the scenery of these hills there is grandeur for the artist and on their slopes there is game for the hunter. Right well do we remember how, on that hot summer day, ever as we climbed this cañon we followed the trail of the huge, flat-footed grizzly, which had recently gone before us. Once made, the pond could be stocked with fish and furnished with yachts and canoes, for the amusement and recreation of one's friends of the hectic cheek. Winding stairways among the cliffs would climb to its level, and, from there, farther up to lofty look-outs among the crags, from which to view the farm beneath, with its orange-orchards and vineyards, its green corn and yellow barley. From there, also, the projector of this plantation could watch the progress of his improvements, and, with the redeemed Faust of Goethe, could find the consummation of happiness in seeing

"Green fertile fields where men and herds are found
In comfort dwelling on new tracts of ground."

And in saying with the same—

"Each day report me and correctly note
How grows in length the undertaken moat.
To countless numbers I would furnish land."

There have been two important investigations looking toward the reclamation of the desert land of California, and it is a noticeable fact that these have not been under the auspices of private companies, nor even of so local an agency as the State itself, but have been authorized by the sanction of the General Government. The first of these has already been dwelt upon; the other, yet in progress, aims at the admission of the Colorado River into the Mohave Desert, a great area of utterly waste land, much of it below the level of the sea, whose thirst an ocean would scarcely suffice to appease. Under the instructions of Lieutenant Wheeler, director of the geographical surveys of the War Department, Lieut. Eric Bergeand, an engineer officer, has in the years of 1875 and 1876 led a scientific corps through that region, traversing the desert by various lines of travel, and observing the phenomena of its meteorology, its plant and animal life, and its physical conditions in general. Thence they followed down the banks of the river and along the shores of the Gulf of California, making a careful topographical survey of the plateau which acts as a levee to restrain the water, and seeking some pass of little profile through which it may be diverted by canal.

Along this stream the engineers worked for weeks, measuring the area of its cross-section, and determining, by accurate base-lines on the land and center, side, and sub-floats in the water, the mean rapidity of its current. From these data they compute the volume of its discharge. Knowing this and the meteorological conditions of the desert to the inland, they are able to tell how great an area of this land could be submerged by this volume of water before the absorption of the soil, and the evaporation from the surface of this artificial sea—the evaporation increasing with the square miles of watery surface—would counterbalance the influx from the river, and then the lake would have its maximum area. Knowing this and other meteorological data they make estimates of the climatic influences to be exerted by such a lake and its tendency to make the desert habitable and available for purposes of life and agriculture.

Accompanying this expedition have been experts in natural science, notable among whom is the German chemist and mineralogist, Dr. Oscar Loew, who will report upon the fertilizing properties of

the earthy matter held in suspension by the Colorado and other rivers, the nature of the various soils and mineral incrustations found, the influence of extreme aridity on the human system, the kinds and limits of vegetable growth, etc. What the result will be, time and the reports alone can tell, but, whatever the event, these studies will surely be a valuable contribution to the world's store of knowledge, and it is by just such endeavors, even if they are unsuccessful at first, that the future science of irrigation is to be built up.

The third question of weighty interest to California is one of agrarianism. It hinges upon irrigation in so far as irrigation increases the amount of arable land, and with such an increase there comes a natural tendency toward small farms and, what is of importance here, toward definite boundaries between them. Of fertile soil a few acres are enough for the needs of a family, but grazing farms are proverbially large farms, and this has been celebrated as a grazing country ever since those days when its principal exports were hides and tallow. Indeed, its millions of sheep, which, by their close nibbling, take out the grass by the roots, are coming to be recognized as a serious disaster to its prosperity, and if irrigation will transform the sheep-pasture into a wheat-field, it will do a glorious work.

Taken in general, that system of almost unlimited possession known as the *rancho*, and that system of immensity in farming in which men are reckoned like cattle, are not good ones. They smack too much of the feudal order of things. In order to make one grandee there must be a hundred peons, and for every great farmer there are a hundred hirelings, and it is better for the State that a man should be master of forty acres than a servant on forty thousand. However necessary and good this apportionment may be for a new country, it is certainly a fortunate day for that country when these vast tracts are sub-divided among industrious immigrants. The division of Southern California into great ranches, varying in area from 10,000 to 300,000 acres, is a heritage of trouble and a drawback to the State. The original grants, by which these lands first became private property, are faulty papers, shiftlessly designating a boundary line to run from a certain tree, which is now cut down, to a certain stump, now rotted away; and taking advantage of this uncertainty, the avaricious land holder has too often stretched the perimeter of his estate so as to take in here a spring of water and there a strip of meadow. Hence have arisen quarrels which have developed into law suits, but the mills of litigation grind slowly, and, in the meantime the squatter on this disputed ground has no heart to work. He fears to establish himself a homestead even in this vicinity, apprehensive that he may be declared within forbidden limits and ousted from his improvements after years of toil. To every patient listener they rehearse the piteous tale of ejectment after ejectment and dwell upon the rascality and perjury of these ranchmen, who are not Mexican dons, as of yore, but American speculators.

Under these circumstances, they say, what heart can we have to build ourselves houses that are homes, and invest our little money in these farms of doubtful title, which the next session of court may wrest from us; we can only "skin" the land while we stay, and be ready to move at any moment. For this reason, finished country houses are very scarce in this land, and the merest shanties are made to serve for residence. For instance, there was the Spaniard, Goleo Farollte, who guided us so well from Santa Paula into the mountains. This man was an old settler of twenty years standing. He owned hundreds of horses, and of cattle, more than he knew. Still better, he owned the respect of all who knew him, for he was an honest and honorable man. Though rich in more respects than one, yet the house where he dwelt was but a scanty hovel, too small for his children to grow in. Still he could not build other, he said, until the almost interminable law suit should be over and he should be left undisturbed in his possession.

So goes the strife; who are right, let time and the jurymen tell, but this I know, that the observer from abroad must have his sympathies well subdued, or he will surely find himself wishing that the spirit of the agrarian dispensation might be introduced into the land laws of Southern California.

IMPORTANCE OF HYDRO-GEOLOGICAL SURVEYS FROM A SANITARY POINT OF VIEW.*

By BALDWIN LATHAM, C. E., M. Inst. C. E., F. G. S., F. M. S., &c.

From "The Engineer."

It is now generally admitted that all supplies of water are due to rainfall; a portion of the rain percolates into the earth and forms a subterranean store, which is almost in universal requisition to supply the wants of man. The amount of rain that percolates into the earth depends, in a great measure, upon the geological character and physical outline of the district. The experiments of Dalton, Dickinson, Evans, Greaves, Lawes and Gilbert, show that the percolation varies in different years, and at different periods of each year, the replenishment of the store of underground water usually taking place in the winter months, and the exhaustion of the store in the summer and autumn months. The amount of water stored in the earth, other things being proportional, is equal to the volume of the strata, or the thickness of the beds. There are, however, other matters which affect the quantity of water percolating, such as the extent and nature of the outcrop of the strata receiving the rainfall, the volume of the strata, the lithological character, and the free communication between different parts. Professor Prestwich states, in his work upon the "Water-bearing Strata of London," that "Oolites, limestones, some sandstones, &c., instead of holding definite quantities of water in proportion to their masses, will hold indefinite quantities proportional only to the number and magnitude of the crevices and fissures by which they are traversed, and the water so held will not pass indifferently in any direction, but must follow the irregular and uncertain channels presented by those joints and fissures. The late Very Reverend Dr. Buckland pointed out that the water held in store by the earth did not, as a rule, maintain a horizontal level, but that its surface possessed a considerable fall in particular directions corresponding to the points of discharge of springs.

The fall of the water line having been established, it is not difficult to perceive that, where a considerable difference in surface level of subterranean water is discernible, this water must be moving in the direction of its outfall or natural vent. Water level, therefore, in subterranean strata, means the line drawn from the highest point at which it accumulates to the lowest or point of vent. Most geological strata in a natural state may be considered to be full to the level of the sea; beyond this there is an extensive store of water above this level, rising, in many districts, to a considerable altitude. The inclined surface of this water is the measure of resistance to the movement of the water in its passage, or, in other words, it is the measure of the element of friction and molecular attraction which interferes with the free discharge of the water, so that the water is retained in its subterranean reservoirs and but slowly delivered from them, the rapidity of the discharge of this underground water depending on the porosity of the strata, and the size and extent of the ducts which convey it to its natural point of outfall.

These subterranean currents, although hidden from view, obey the same laws with reference to their flow as streams which move on the surface of the earth; elevations, faults, and artificial works may interfere with their flow. The late Very Rev. Dr. Buckland observed that the elevation of the subterranean water between the town of Watford and the highest spring that issued from the neighboring chalk hills was 300 ft. in a distance of fourteen miles. In 1842 the Rev. James Clutterbuck made a communication to the Institution of Civil Engineers, in which it was stated that the replenishment of the chalk north of London usually occurred between December and March, and that the water accumulates in the chalk proportionally as the point of observation is removed from the river or natural vent of the water, and that the water in the chalk when full falls be-

* British Association.

tween April and November, the variation in level in the upper chalk exceeding fifty feet. In 1843 he further stated, at a meeting of the Institution of Civil Engineers, in reference to falls of water in the chalk: "It is then shown that a line drawn from a point three miles south of the Colne, at the level of that river, or 170 feet above Trinity high-water mark, at mean tide level in the Thames below London Bridge (a dip of 180 feet in fourteen miles, or an average inclination of thirteen feet per mile), cut the water level at the point whence it is drawn at Hendon Union Workhouse, and at Cricklewood between that place and Kilburn, whence it may be inferred that up to this point there is no apparent trace of a depression of level caused by the exhaustion of water under London." In a communication from Mr. John Evans, F.R.S., to the Institution of Civil Engineers in 1861, it is stated:—"The inclination at which water would stand in the middle chalk north of London was, under ordinary circumstances, at least thirteen feet six inches to the mile, which was proved by the streams generally running at about that slope. It was evident that if water could pass through the chalk with that inclination it would find its way by some underground passage instead of by the streams. In its lower beds the chalk was of a nature to increase the friction, and it would be found that in the neighborhood of Berkhampstead the water stood at an inclination of about nineteen feet six inches to the mile, and in some parts of Kent and elsewhere at as much as forty feet to the mile." Professor Prestwich, in his work on "The Water-bearing Strata of London," states that the fall of water in the tertiary beds is about five feet per mile at Garrett, and four feet per mile at Waltham Abbey, while the well of Grenille, in the lower greensand, indicated a fall of two feet per mile.

The results of a hydro-geological survey, made by the author, of the neighborhood south of Croydon, show that there is considerable variation in the fall of the subterranean water.

In all cases the fall of subterranean water decreases as the exhaustion of the strata proceeds.

A hydro-geological survey of East Dereham, Norfolk, made by the author when prospecting for the site of waterworks, shows that in the case of wells sunk in the boulder clay overlying the chalk, the level of the surface of the subterranean water varies in the town from two feet per mile in the flat table land to 100 feet per mile in the valleys. The movement of the subterranean water appears to have been known even in classic times. We find it recorded that in the war between Cæsar and Pompey, when at Petra, Pompey suffered very much. They could get no water on the rock, and when he attempted to sink wells Cæsar so perverted the water-courses that the wells gave no water. Cæsar tells us that he even dammed up the streams, making little lakes to hold it, so that it should not trickle down in its underground courses to the comfort of his enemies.

No question can be of more importance, from a sanitary point of view, than that of the supply of wholesome water. It is known that water does not in itself change in character, but it becomes noxious as it is made the vehicle for conveying injurious matter. Hippocrates appears to have been aware of the importance of pure water, and, moreover, of the best places for its selection, or as it has been stated, "upon the aspect of its sources as well as upon its elevation." Mr. Simon, of the Medical Department of the Privy Council, in his report of 1869, stated that "the doctrine in general terms, that a vast influence is exercised over the health of communities by the quality of the water which they consume, is one which, as far back in literature as any reference to such questions could be expected to exist, may be seen to have universal medical consent in its favor; and, during long ages of history, the common instincts of mankind were even purer and stronger than undeveloped science. Of the many invaluable additions and improvements which medical knowledge has received within the last quarter of a century, scarcely any can, in my opinion, be compared for present practical importance to the discoveries which have given scientific exactitude to parts of the above stated general doctrine, and have enabled us definitely to connect the epidemic spread of bowel infections in this country with the existence of certain faults of water supply.

Not only is it now certain that the faulty public water supply of a town may be the essential cause of the most terrible epidemic outbreaks of cholera, typhoid fever, dysentery, and other allied disorders, but even doubts are widely entertained whether these diseases, or some of them, can possibly attain general prevalence in a town except where the faulty water supply develops them." Such may be said to be the testimony of one of the highest medical authorities in this country. Authorities in other countries have likewise drawn attention to the importance of the purity of water supplies, and, moreover, Professor Pettenkofer has shown that there are in some cases certain definite relations between epidemics of enteric fever and cholera and the state of the level of the ground water.

In the year 1870 the author was called upon by the Croydon Local Board to inquire into the state of health of the inhabitants of a cluster of sixty-nine houses situated in the hamlet of Wellington, near to the Sewage Irrigation Works of the Croydon Local Board. The author then reported that in all the houses in which the cesspools were placed on the north of the habitations they had been, so far as was known to the present inhabitants, entirely free from any zymotic disease, whilst those with cesspools located in other aspects the tenants had suffered at different times from various kinds of zymotic disease. At that time the author attributed it to the effect of the prevailing winds wafting any miasms in the direction of these houses, but more careful investigation shows, with respect to these houses, that the current of underground water is from south-east to north-west, and that the well and the cesspool are invariably on opposite sides of the house. In all cases in which the well is located, as respects the fall of the subterranean water, above the cesspool, the house has been invariably healthy, and in every case in which the cesspool is located above the water supply that house has, so long as the water from the well was in use, never been long free from enteric fever; in fact, the use of water from most of the wells so located has been prohibited by the medical gentlemen in attendance on the occupants of these houses.

During the past year an outbreak of enteric fever having occurred in the parish of Coulsden, near to Caterham Junction, south of Croydon, and knowing that the inhabitants of these houses had previously suffered from outbreaks of this fever, the author found that in the case of all the occupants of all the houses affected with the disease the cesspools were situated on the subterranean current above the well, so that polluting matter must naturally be carried by the movement of the water into the well.

Numerous other cases in different parts of the country have also been brought to the author's attention which clearly show that, in many instances, if attention had been paid to the subterranean movement of the water, and the sites of the wells and cesspools exchanged, much disease and death would, in all probability, have been prevented. The periods at which epidemics of cholera, enteric fever, dysentery, and diarrhœa occur, show that usually they have reference to the low state of the springs, when the movement of the water is least active, and therefore when the concentration of impurities is the greatest. It has been very clearly shown that the movements of underground water do influence the health of populations. In the "Transactions" of this Association for 1837, it is mentioned in a paper by Mr. Urquhart, that the plague at Constantinople is shown to have particularly affected districts in which the burial grounds stood above the places afflicted. In the Seventh Report of the State Board of Health of Massachusetts, an example of drainage from a cemetery affecting health is given:—"That mentioned by Pietra Santa, of the villages of Rolendella and Bollita, in Italy. The cemeteries of these villages were at the summit of a wooded hill, at a considerable distance from the houses. The spring from which water was obtained was at the foot of the hill, and ultimately the water became highly contaminated. A severe epidemic which recently visited these villages was ascribed to the use of this impure water. A similar case occurred during the past year at Barbary, as an incident of the plague which has recently visited that country. The people of a certain village

lived in excavations in rocks, getting their water supply from wells into which water had run from the cemetery where bodies were covered only a foot deep with gravel. Those only who drank this impure water were attacked with plague." So important is this matter considered in some countries, as to the contamination of drinking water by proximity to cemeteries, that regulations have been laid down as to the distance from which they shall be from inhabited districts. In Italy no well is allowed to be sunk within one hundred yards of any cemetery, and double this distance is required in France and Austria. This is called the "protective distance," but has, in some cases, been thought to be too small.

The Hygienic Council at Brussels in 1852 decided that a distance of 400 yards was protective, but even this distance has been sometimes conceived to be inadequate. In Prussia no cemetery is allowed within 500 paces of any dwelling. At Lausen, on the railway between Basel and Olter, the morbific matter of disease was carried a distance of two miles through a hill to the village on the opposite side, as recorded in the Fifteenth Annual Report of the Army Medical Officer. This latter village, however, was below the point at which the infectious matter was carried, but on the direct line of flow of the subterranean water, as was subsequently proved by experiment. The safe distance with regard to the influence of cemeteries and other sources of contamination on the water of wells will depend upon the position of the point of pollution with reference to the water supply. A well situated a few yards above a cemetery with regard to the flow of the water may be perfectly safe, whereas one located below a cemetery, on the direct line of flow, present experience shows that no reasonable distance can be said to be a safe limit. So long since as 1827, it was shown by Professor Liebig that nitrates existed in twelve wells in the town of Giessen, but none was found in wells two or three hundred yards from the town. The direction of the flow was not given in this case. Examination of waters both within and without a town, or waters flowing to or from a town, give a marked difference in a chemical point of view. In the "Transactions" of this Association for 1851, Dr. R. A. Smith says with regard to the impurity of well water, "The number of cases of sickness from these causes is, I am inclined to think, greater than is believed." This expression had reference more to impurities that might be supposed to pass into the wells from their unprotected state, than being due to the position of the well itself, in reference to the causes of pollution; but the fact is recorded by a careful observer that well water, under certain conditions, does not minister to the health of the persons using it. The baneful effects of storing or nurturing excrementitious matter in receptacles in close contiguity to our water supplies are patent, at times, to the most casual observer, but the public, and many professed sanitary reformers, are not thoroughly alive to the magnitude of the evils due to this cause.

A careful hydro-geological survey will show the directions in which subterranean water is moving, and may enable the residents of country houses to locate their well for procuring a supply of water, and the cesspools in such a position as to avoid impurities passing from the cesspool to the well, but as a general rule, no consideration is given to this matter, and it is usually seen that the cesspool is so located that it leads to the pollution of the water supply; or the underground current, after receiving its load of impurities, slowly passes under the dwelling house, and as the soil under the house from being protected from the weather will invariably be found to be cracked and fissured to a considerable depth, impure aëration takes place from a polluted ground atmosphere. It is a singular fact that all epidemic outbreaks of enteric fever, whether directly ascribed to the influence of water or to milk, in every case of the water used had been procured from wells.

It was shown with reference to the outbreaks of cholera in the metropolis that the relative intensity with which this disease attacked various parts, that nearly the whole force of the blow was expended on the lowest levels. Moreover, from the reports published by Dr. Laycock in the first volume of the Report of the Commission on Towns, with respect to York it is shown that in

the sweating sickness of 1550 and 1551, and again in the plague of 1604, that these epidemics exhibited the same relation with regard to season of the year as exhibited in modern times by other epidemics.

In conducting a hydro-geological survey it should be thoroughly borne in mind that, as a rule, water underground follows the natural inclination of the surface of the district, but there are exceptions to this rule. There are also circumstances which may modify the flow of water, such, for example, as the abstraction of a large volume of water at a particular point by pumping from a well, which well would become the center for a drainage area extending, in all probability, to a considerable distance from the well, or in some flat districts the elevation of the water line of a river, in time of flood, may reverse the direction of flow, for some distance, of the under-ground water, unless, as is the case in some wells which are known to be tidal, the volume of water flowing to the river is very large. It is scarcely possible in a town where there are so many points for pollution to so locate a surface-well as not to be affected by some of them. The use of the water from surface-wells located within a town ought, therefore, to be prohibited being used for domestic purposes. In villages the wells should be located outside and above the village in reference to the flow of subterranean water. The same remark applies to the well for procuring a supply of water to a private house.

It is rather singular that while measures are being adopted for the prevention of the pollution of streams flowing on the surface, and which, by the way, have never been traced to be the cause of disease, no one has thought of the great evils that have resulted, and will result, from the pollution of the underground sources of water supply. The object of the author has been to direct attention to this all-important subject, and to point out, in cases where the use of cesspools is unavoidable, that there are ways in which they may be introduced without detriment to the health of the person using the water, which possibly can only be procured from a local well.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The Society sent out in December the following to all the members, calling for their vote.

Special Ballot.—By order of the Board of Direction, the following, presented at the Eighth Annual Convention and then referred to the Board, is, without comment, submitted to vote by letter ballot;—

"*Resolved*, that the American Society of Civil Engineers will further by all legitimate means, the adoption of the Metric Standards in the Office of Weights and Measures of Washington, as the sole authorized standards of weights and measures in the United States; that the chair appoint a committee of five to report to the Society a form of memorial to Congress, in furtherance of the object expressed; and that the foregoing be submitted to the Society and voted on by letter ballot."

Shall a committee be appointed for the purpose set forth?

BOSTON SOCIETY OF CIVIL ENGINEERS.—A valuable paper on the Ventilation of the Hoosac Tunnel, was lately presented to this Society by Thomas Doane C. E. We shall soon publish it.

IRON AND STEEL NOTES.

RUSTING OF IRON.—In vol. 218 of *Dingler's Polytechnic Journal*, pp. 70-79, will be found the results of a series of experiments made by A. Wagner, on the production of rust upon slips of iron exposed to water containing various salts in solution, and in the presence of air free from carbonic acid, and of air containing that gas at various temperatures, and also in sealed tubes from which the air had previously been expelled.

We must refer to the original paper for details, but may here mention that, whilst pure water in presence of air caused the iron to rust, this was found to occur more rapidly if carbonic acid was present at the same time, and the production of rust was materially increased by the presence of the chlorides of magnesium, ammonium, sodium, potassium, barium, and calcium, the first-mentioned being the most active in this respect.

Iron immersed in river water concentrated by evaporation was found to rust more slowly than when in distilled water, and whilst the presence of oils or fats greatly diminished the rapidity of rusting, it was found that alkalies prevented it entirely. A solution of chloride of magnesium, in the absence of air, attacked iron at the temperature of boiling water, but solutions of the chloride of sodium, potassium, barium, or calcium, were not found to do so.

DETERMINATION OF PHOSPHORUS IN IRON AND STEEL.—At the February meeting of the American Institute of Mining Engineers a paper was read on this subject by Mr. Andrew A. Blair, of the Watertown Arsenal, in Massachusetts, and although the process described by him is not new, it has some features in its details which, we think, will render its re-production acceptable to chemists engaged in

similar investigations. Five or ten grammes of the borings are treated with strong nitric acid, adding from time to time a few drops of hydrochloric acid, and applying heat until the solution is complete. The solution is then evaporated on a water bath to a syrupy consistency, twenty to forty cubic centm. of hydrochloric acid added, the beaker covered and heated until all action has ceased, when the cover is washed down and the solution evaporated to dryness. This operation is repeated, and when the residue is dry it is re-dissolved in hydrochloric acid, and when the solution appears to be complete, an equal volume of water is added to it, and the solution boiled for a few minutes to convert any basic or pyrophosphate of iron that may have been formed by too high a temperature into the orthophosphate. The solution is then diluted and filtered, the filter worked with dilute hydrochloric acid, and then with hot water, and the filtrate diluted to about 750 cubic centm. To this is added a sufficient quantity of acid sulphite of ammonium, to reduce all the ferric to ferrous salt. This reduction is facilitated by rendering the solution as neutral as is possible by ammonia, even adding as much, after the sulphite has been added, to render the solution turbid. This slight precipitate may be re-dissolved by adding a few drops of hydrochloric acid; and when the reduction is complete, and the solution has been heated to boiling, an excess of hydrochloric acid is added to decompose any excess of the sulphite, and the whole boiled until every trace of sulphurous acid has been driven off. Although an excess of acid in the first place interferes with the perfect reduction of the ferric salt, when this is complete, the excess prevents subsequent oxidation and facilitates driving off the sulphurous acid. The solution should be kept boiling briskly, the beaker being covered by a large watch glass and stirred frequently but cautiously, as the solution has a tendency to boil over when suddenly agitated. Once the smell of sulphurous acid is gone, the beaker should be put into cold water, and the water renewed until the solution is cold. Dilute ammonia is then added until a slight precipitate of green protoxide of iron remains undissolved after stirring. A decided excess of acetic acid is then added, which re-dissolves the protoxide of iron, whilst the ferric phosphate remains insoluble. A few drops of ferric chloride are now added, and the solution heated to boiling. The precipitate should now have a decided reddish color, owing to excess of ferric oxide thrown down with the phosphate, this indicating that all the phosphoric acid present has been precipitated as ferric phosphate. The cooling of the solution previous to the precipitation of the phosphate is to prevent the formation of a hard scaly oxide of iron during the subsequent boiling. The solution, when heated to boiling, is filtered as rapidly as possible through a close filter, the solution being kept boiling all the time, the beaker is washed out, and the precipitate on the filter, several times with boiling water. The filtrate should be quite clear, which is always the case when sufficient excess of acetic acid has been used. When clear it never contains any phosphoric acid, but if cloudy during filtration, owing to too little acetic acid or to so much ammonium, it always contains phosphoric acid. This is due to the fact that, although ferric phosphate is insoluble in acetic acid, it is very soluble in ferric acetate, and also in sulphurous acid, should the latter not have been entirely boiled off. The more neutral the solution the greater its tendency to oxidation, which accounts for the favorable action when an excess of acetic acid is added. The precipitate on the filter, and adhering to the sides of the beaker, is dissolved in strong hydrochloric acid, the filter well washed with hot water, and if the solution exceeds forty or fifty cubic centm. in bulk, it is evaporated down; sufficient citric acid is then added, to prevent the precipitation of the ferric oxide on the subsequent addition of ammonia, then magnesia mixture, and finally an excess of ammonia; the entire solution should not exceed seventy-five cubic centm. in bulk. It is cooled in ice water, and when perfectly cold is stirred carefully until the ammonia, magnesia, and phosphate, is seen to be precipitated; then, after standing in ice water for some time longer, it is stirred vigorously several times and allowed to stand at least from eighteen to twenty-four hours before filtering. When filtered, without washing, the precipitate still remaining in the beaker, and that on the filter, is dissolved in hot dilute hydrochloric acid, a little citric acid added, and the ammonia magnesian phosphate again precipitated by adding excess of ammonia, using the same precautions as before; filtered after standing twelve to twenty-four hours, washed with very dilute ammonia water, and then dried, ignited, and weighed as magnesian pyrophosphate.

With regard to the determination of phosphoric acid by the molybdate of ammonia process, it has been recommended by both Rose, Frezenius, and others, that all silica should be removed from the solution previous to the precipitation. Mr. E. H. Jenkins, however, in a paper in the March number of the *American Journal of Science*, entitled "The Effect of Silicic Acid upon the Estimation of Phosphoric Acid by Ammonium Molybdate," has made an experimental enquiry into the question, and comes to the conclusion that "in no ordinary case" is a previous separation of silicic acid necessary to ensure all desired accuracy in the estimation of phosphoric acid by the molybdic method.

RAILWAY NOTES.

CANADA, on the 30th of June, 1875, had 4,484 miles of railway in operation, which has now probably been increased to 4,500 or more. In 1850 the amount was only fifty-one miles; in 1855 it had jumped to 1,218; in the next ten years it was nearly doubled, reaching 2,231, and in the next decade to 1875, it had again nearly doubled, rising to 4,484 miles—a rate of increase just about the same as that of the United States. The number of inhabitants in Canada per railroad mile is about twice as great as in the United States, while the number

of square miles of area per railroad mile—153—is nearly four times as great; so that there is a much greater field for railroad operations in the Dominion, if only the extent of territory be considered, than in the States. Owing to the inhospitable climate of much of Upper Canada, however, those regions will not be fully developed until the temperate zone is peopled, but the Canadian Government and people are showing commendable enterprise in railroad building, and a few years will find a large additional area opened to cultivation and civilization.

A Swiss inventor envelopes the driving axle of locomotives in coils of insulated copper wire, and by the passage of an electric current converts the wheels into powerful magnets, with increased adhesion to the rails. This is charming, with the exception that numerous patents have already been taken for the same thing, and that it will not and could not work with any practical effect. The Swiss gentleman referred to has brought out something at once new and good.

The mean duration of rails of Bessemer steel is, according to careful experiments in Germany, about sixteen years. On the other hand, ten years of trial at Oberhausen on an experimental section of the line between Cologne and Minden has shown that the renewals during the period of trial were 76.7 per cent. of the rails of iron of fine grain, 63.3 of these of cementation steel, 33.3 per cent. of those of puddled steel, and 3.4 per cent. Bessemer steel.—*Annales Industrielles.*

English and American Locomotives.—It has already been announced in our pages that the Midland Railway Company have entered into contracts for the purchase of twenty passenger locomotives, at a cost of £2,500 each. The *Railway Age,* an influential American contemporary, commenting on this statement, says:—"American locomotive builders would be glad to furnish a good class of engines for $8,000 to $9,000 each, and we presume would build as good ones as those required by the Midland for less than $12,000. They are already sending their locomotives to several foreign countries. Perhaps England will become a customer also." This is an assertion which deserves attention. In this country it would be impossible to obtain engines at all comparable with those used on the Midland Railway for £1.800; but it is a noteworthy fact that this has been said to be the cost of Mr. Webb's latest locomotives built at Crewe. We do not vouch for the accuracy of the statement. It appears to be proved that American locomotives are cheaper than English locomotives, and that they do as much work in their way, and do it as well; but the working conditions are so various that there is nothing certain on the subject. We wish some one of our great railway companies would buy an American locomotive, and try for themselves whether there really is anything peculiarly advantageous in a much-vaunted system of construction. If there is, we fancy as good locomotives could be built on American patterns at this side as on the other side of the Atlantic. If there is not, then a good deal of boasting would probably be silenced, at least for a time.

Some interesting observations on the injurious effects of snow on steel rails are communicated from an Austrian line of railway, the Kaiser Ferdinand northern line. A portion of this line, about eight English miles in length, between Floridsdorf and Wagram, is very open, and often blocked with snow in winter time. The obstacle is generally surmounted by strewing sand over the rails in front of the driving wheels to increase their bite, and putting on extra steam. This portion of the line in question has a double line of metals, formed partly of Bessemer steel rails and partly of light Martin steel rails weighing about 30.50 kilogrammes per running meter. Now, the slipping of the wheels frequently caused heating of the tires and rails, which are suddenly cooled again by the low temperature of the air or the falling snow. This, in itself, must be injurious to the molecular construction of the metal. But, beside, the increased friction causes a certain amount of abrasion of the upper surface of the rails at the spots where the stoppages have occurred. Examinations proved that these abraded portions varied in length from two to nine English inches in length, $\frac{1}{32}$ inch to $\frac{1}{4}$ inch in depth, and extended over the whole breadth of the rail. A train in passing over the depressions so caused necessarily experiences a certain shock, and it is reasonable to suppose that the concussion thereby communicated to the rail will be most felt when the ground beneath is frozen hard, so that the natural elasticity of the rail has no room to play. In three instances rails so worn snapped asunder suddenly at the abraded portion, although no flaw or defect in the metal could be detected. This led to the removal of all abraded rails from this section of the line, amounting to twenty-eight lengths of Martin steel rails, and ten lengths of Bessemer rails. No similar case of fracture is known to have occurred in the iron or puddled steel rails previously in use, although the amount of abrasion they underwent must have been at least as great. The inference is that the improved rails of Bessemer and other steel, their superior strength notwithstanding, are less capable of withstanding concussion than the older rails, and consequently whenever they are used increased vigilance is requisite to prevent accidents in the winter time.

Mr. J. B. Fell lately read a paper "On Experiments made at the Camp of Aldershot with a New Form of Military Field Railway for Rapid Construction in Time of War." He explained that he had the permission of the Secretary of State for War for reading his paper, which gave the results of experiments which the Royal Engineer Committee at Chatham had carried out at the camp at Aldershot, of which Captain Luard, C. E., and himself had charge. The experimental railway, he said, consisted of a succession of timber viaducts, which supplied the place of earthworks, culverts and bridges, and which, when the

materials have been prepared, could be erected with great rapidity. The conditions the committee desired to have fulfilled in the trials were that an engine not exceeding six tons weight should take a train of thirty tons up an incline of one in fifty and travel at an average speed of ten miles and a maximum of twenty miles an hour. The wagons were required to carry a load of three tons dead weight each, and from 300 to 500 cubic feet of bulky articles, such as tents, hay and commissariat stores. A seven ton seige-gun was to be carried on two wagons, and it was to be shown to be practicable to construct one mile of railway per day, over such ground as was selected by the committee at Aldershot, by the labor of 500 men. The experimental railway was one mile in length, gauge eighteen inches. Steepest gradient one in fifty, the sharpest curve three chains radius, and one of the viaducts was 660 feet in length, and twenty-four feet in height. The structure was of a simple form, and consisted of two beams which were bolted to a kind of trestle-work supports which were sunk to a depth of twelve inches and firmly fixed in the ground. The rails being laid on the beams completed the railway, for the construction of which no other than military labor was required. The experiments occupied at intervals a period of twelve months, and the committee came to the conclusion that the result of the trial had proved that the above-named conditions had been complied with in every particular, and even exceeded. It had been shown that a single line of field railway, constructed on the plan employed at Aldershot, would be capable of carrying ammunition and commissariat stores sufficient for the supply of an army of 100,000 men; that a double line and day and night service would be capable of supplying an army of 300,000 men; that a single line of railway could be made over ground like that at Aldershot at the rate of two miles a day by 500 men; and that if it should ever be required it would be possible to construct a field railway at a speed at which 100,000 men could march. An ordinary transport ship accompanying an expedition would carry the materials and rolling stock for twelve miles of railway of two feet six inches or three feet gauge, to be worked by engines of ten tons weight and wagons carrying six tons each, and the railway could be made for about £5,000 per mile, the cost of erecting included.

ENGINEERING STRUCTURES.

THE CHANNEL TUNNEL.—The British Society of Engineers publishes the following details of the preliminary works for the tunnel under the channel. The year 1875 was profitably employed. The outlay amounted to 61,000 francs, the half of which, or 30,500 francs, had been expended in geological researches at the end of December, as shown in the report presented at the first general meeting on the 15th of March, 1875, by M. Lavalley. The result of the first year's labors is contained in four reports, which were then distributed, and which describe the bases on which the studies are founded. This year the surveys have continued on a larger scale. In 1875, 1,522 soundings were taken, of which 753 brought up specimens from the bottom of the sea. The engineers had at their service the Pearl, a small steam tug with insufficient appliances, and with which they worked between August 10 and September 21, during which time they could only leave the port of Boulogne twenty times. This year the soundings have been effected on the English side with a large vessel fitted with a crane and better provided. The work commenced at the beginning of July, and the vessel is stationed at Dover, which port it can enter or leave at all hours. Greater progress in the formation of the company has, however, been made in France than in England. The 2,000,000 francs required for the preliminary surveys have not yet been raised.

A PORTION of a tunnel which is being built under Cavendish Court, Houndsditch, connecting the Metropolitan Railway from Bishopsgate to Aldgate, gave way lately, burying beneath the ruins a number of workmen, and carrying with it a horse and cart and the driver. Four men were taken out dead, and five so dreadfully hurt that small hopes are given of their ultimate recovery.

THE TALL CHIMNEY AT GLASGOW.—There are few chimneys which have any peculiar historic interest, but an exception is presented in one built at Glasgow by Mr. Joseph Townsend, and attached to that gentleman's chemical works. This chimney is to its neighbors what Mount Blanc is to the rest of the Alps—a giant among pigmies. The foundation of this chimney was laid in March, 1857, and on the 6th of October, 1859, the coping was added at the top, at a height of 468 feet from the foundation, and 454 feet from the level of the ground.

At the foundation the outside diameter is 50 feet, and at the surface it has diminished to 32 feet, while at the top of the coping the diameter is 12 feet 8 inches. On the 9th of September, 1859, and while the chimney was still unfinished, and therefore before the mortar was dry, a storm occurred which resulted in swinging the chimney out of the perpendicular to the extent of five feet at the top. This accident, though perhaps directly due to the storm, had its origin in a neglect in the building process. Proper allowance had not been made for the contraction of the mortar used in setting the bricks, and as a consequence a certain number of planks were under a great pressure, being arched in the centre. Suddenly one of these at one side gave way in the oscillation caused by the storm, and with the unequal pressure the chimney was then forced from the perpendicular to the extent above stated. That the accident occurred in this way Mr. Joseph Townsend ascertained by personal observation. For a time some fear was entertained that the whole chimney would come down, but on the 21st of the same month measures were taken to prevent this, and by the 1st of October, the whole was restored to the original upright form. This was effected by sawing the chimney on the side nearest to

an imaginary straight line. The following figures give the intervals at which cuttings were made :

1	....	128 feet from the top.	
2	....	49 feet below	1
3	....	22 "	2
4	....	15 "	3
5	....	12 "	4
6	....	19 "	5
7	....	20 "	6
8	....	13 "	7
9	....	20 "	8
10	....	30 "	9
11	....	40 "	10
12	....	40 "	11
13	....	41 "	12
			449 feet.

When the chimney was only two years old, it was struck by lightning, and a fire ensued, the composition gas-tubing being melted at a distance of 100 feet from the gas meter, though this latter was situated twenty feet from the chimney. To understand how this happened, it is necessary to state a few additional facts. The chimney was provided with an electric conductor on one side, and a coil which united with the conductor near the ground, where together they were bound to an iron rod and passed through a well of water, situated near the side of the foundation, seven feet square and two feet deep, and thence down about eight feet into the earth. Now, into this well comes the drainage of the works, and, further, the discharge pipe from a water-closet, and it was found, on investigation, that although the pipe actually discharging into the well was of stoneware, yet, further back, it was in connection with one of cast iron. This latter pipe, being midway between the conductor and the gas composition tubing, must have served as a vehicle for the electricity, which must then have completed its circuit by the gas pipe, which was thereby melted, and, the gas escaping, caused the fire.

To prevent the recurrence of such an accident the cast iron pipe was removed and one of stoneware substituted. All now went well till three years ago, when the chimney was again struck by lightning at 150 feet from the top, thirty bricks being then dashed out. Again an examination was instituted and it was found that a separation had been effected between the conductor and the rod of iron with which it was bound where it passed through the well at the bottom. This separation had probably happened before the accident occurred and so possibly caused it. A new rod ten feet long and passing eight feet into the earth was now substituted for binding the conductor and coil together, and the whole was well tallowed to prevent oxidation, and was finally enclosed in a wooden box, of which the side of the chimney made the fourth. But a year ago the chimney was once more struck by lightning on the opposite side to that which was last attacked, that is, on the side along which descends the conducting rod. On this occasion a part of the coping stone was knocked off and Mr. Joseph Townsend impressed with the necessity of making some material change in the whole system of protection from lightning, is now providing the chimney with an apparatus which it is to be desired will fulfil its object.

This arrangement may be described in a few words. On the top of the coping-stone are fixed four equidistant rods about three inches wide and one inch thick ; these terminate in stars or arrow-heads, and above them in the centre ascends a rod twenty feet long and higher than the rest, terminating in a double arrow-head. All these are properly connected with bands of iron, and are placed in good communication with the electric conductor and coils.

As may be readily imagined, there is some difficulty and not a little danger in raising such masses of iron to the height of 470 feet, but still more difficult and dangerous is it to construct the apparatus at the top, and fix it and bolt it together as is required. For besides the exposure of the workman to the gases from the chimney, the atmosphere is often highly electric at that height, and freedom from sudden wind cannot be ensured. The construction is nevertheless approaching completion, and the whole of it has been done by one man, Mr. R. Hall. He is, perhaps, the only man who would undertake such work, and yet he does it with scarcely a sense of danger, and certainly with none of fear. It seems as easy to him to walk about and work on the coping stone as it is to many of us to walk about on the ground.

In concluding this sketch, which we hope may prove of some interest to manufacturers who have tall chimneys attached to their works, we would merely point out that not a little success of the working of an electric conductor, depends upon the way in which it is sought to distribute the electric current over the earth. It is not sufficient simply to pass the rod down so many feet into the ground, but it should terminate preferably in a plate or sheet of iron, so as to present a good surface for diffusion.

ORDNANCE AND NAVAL.

NOVELTY IN MARINE ARCHITECTURE.—The Canadians find the ice which for nearly six months every year blocks the St. Lawrence, a great barrier to direct European trade. How to overcome it is a problem their shipbuilders have been endeavoring to solve, and there has recently been launched at Quebec, a vessel designed for making winter voyages down the St. Lawrence to Prince Edward Island. If she is successful other and larger vessels on the same model may be built for European trade. She is named the *Northern Light*, and will be fitted for sea by November. She is sheathed with one of the hardest of woods—greenheart —and plated with iron. Her construction is such that there can be no right-angle pressure from ice on any part of the hull. The draught of water aft is seventeen feet, and the screw is so placed that there will be at all times at least five feet of water above the upper blades, so as to prevent contact with ice. Her engines will be of 700 nominal horse power.—*Iron.*

THE SPEZIA EXPERIMENTS.—We understand that Mr. Nathaniel Barnaby, C.B., Director of Naval Construction to the Royal Navy, is about to proceed to Spezia to examine the results of the recent experiments with the 100-ton Armstrong gun, upon the iron and steel plated targets, as it is felt by the authorities that it may be desirable for us to adopt steel, instead of iron, for our armor plating, and there is even some talk of replacing the iron armour plates of the Inflexible with steel, if Mr. Barnaby should report as favorably concerning that material as the accounts already received non-officially lead the Admiralty to expect. The enormons and startling improvements both in artillery and armor plating, which are daily being made, most conclusively, we think, show the wisdom of the policy which has been adopted in our navy, and which we have consistently upheld, viz., that we should advance by slow degrees, and when we think we have got the type of the fighting line of battle-ship, to build only one or two experimental vessels, instead of a large fleet, as we may be certain that before the year is out some fresh improvement is sure to be made which will necessitate a new design. The Inflexible has been built to carry four 81-ton guns, and already the construction of a 160 ton gun, the size of which would prevent its being carried in the turrets of the Inflexible, is talked of. We are pleased that Mr. Barnaby is going to Spezia, but we doubt that steel is better than iron.

THE NAVY DEPARTMENT of Turkey is one of the eight ministerial departments of the Divan. Turkey has now seven ironclad frigates. The two largest ironclads are the sister ships Mésondivé and Mendonhijé, launched in 1874. They are 9,000 tons displacement, have a main deck battery of twelve 18-ton guns, projectile 400 lb. The forward and after ports of the casement are cut at an angle, so as to answer for bow and stern chases. The casemate is of twelve inch iron, and the hull is protected by twelve inch belt, the deck forward and abaft the casemate being shell proof. The spur is of unusual strength and below water. Two six ton guns on forecastle, fire directly ahead, one gun abaft of same calibre, fires directly astern. On spar deck are six 20-pounders, probably for saluting—total 21 guns. The Azizieh, 900, 16 guns; the Orkanieh, 900, 16 guns; the Mahmoudieh, 900, 16 guns; the Osmadieh, 900, 16 guns; and the Athor-Terfik, 750, 8 guns. There are also five ironclad corvettes carrying four or five guns each, and the two monitors, Hejzie-Rahman and the Loufan Djelil, carrying two 150-pounders each, and two light guns. The twin-screw ironclads Aoni Illah (help of God) and Muin Taffer (aid to victory) are sister ships of 1,400 tons armor, five and a half inch. Four 12-ton rifle Armstrong guns, 250-pounders, are mounted in a central battery, so arranged as to admit being fired ahead or astern. These two vessels are said to possess very high rate of speed.

MORE MONSTER GUNS.—If the advice of the Woolwich authorities had been taken long ago, we should, observes the *Daily News*, probably not now have to deplore the possession of a fleet which, however imposing in appearance and really powerful in offensive armament, is yet defensively so weak that the armor-plating of our most formidable ironclad can be readily pierced by the 100-ton gun recently built for the Italian Government, a weapon which does not by any means represent the limit of power that can be reached by modern artillery. Messrs. Armstrong & Co., for the Italians, and Messrs. Krupp, for the German navy, have probably facilities at their factories for turning out guns of the highest calibre yet reached sufficient to arm, by the beginning of next summer, all the ironclads at present in existence in those countries, whereas the building of a ship to resist the force of their projectiles would be a labor of some four years. The very common-sense advice of the heads of the Factory Department at Woolwich was that the greatest possible power of any single piece of artillery should be approximately ascertained before large numbers of costly ironclads were built which a great increase of velocity and energy in heavy projectiles might soon render comparatively useless. In this opinion, expressed ten years ago, they clearly anticipated the day of such monster guns as the "Woolwich Infant" of eighty tons, and the latest production of the Elswick firm, which weighs something over 100 tons. Instead of this, however, public and private yards in various parts of England were busily employed in building numerous ironclads, the thickness of the armor-plating of which was calculated on purely theoretical bases, so far as the penetrative power of the artillery that might be brought against them in the future was concerned. The result is that we have not a ship in the English navy capable of withstanding a direct hit from the great Armstrong gun, or even from the 80-ton Fraser gun, which will soon be tried for pentration at Shoeburyness, and which will, in the opinion of our most experienced artillerists, be found capable of doing all that the Italian 100-ton gun has yet accomplished. It is some satisfaction, however, to know that in this respect other countries are at a still greater disadvantage, while there is every reason to believe that Woolwich is quite prepared to hold its own against the world in the matter of heavy ordnance, and to begin building, at a week's notice, Fraser guns of greater calibre and power than the highest triumphs of Elswick or Essen.

Thanks to the exhaustive trials at Shoeburyness and Woolwich, the results, and even every detail of which have been open to the world, data have been furnished whereby one of those firms at least, has been enabled to steal a march on our own gun factories. But the advantage is happily only temporary, for Woolwich is now in a better position to build guns of 200 tons than it was to undertake those of 80 tons when the order for manufacturing an experimental weapon of the latter weight was first issued. Designs for a gun 164 tons have been for some time in the hands of the War Department, but it is now almost certain that this immense calibre will be sur-

passed, and that the pet piece of ordnance for the English navy of the immediate future will be a Fraser gun, weighing about 200 tons, 50 feet in length, having a bore of twenty inches, and throwing, with a powder charge of something like 800 lb., a projectile weighing from 3900 lb. to 4,000 lb., or considerably over a ton and a half. As we have said, Woolwich is quite prepared to undertake the construction of such a weapon, and the only obstable in the way is the difficulty of providing working space in a turret for such a monster. The question of weight is not so material as that of length; and it was the opinion of Admiral Boyd (Director of Navy Artillery) and Mr. Barnaby (the chief Constructor) that 164 tons represented the extreme limit for turret-guns in such ironclads as the *Inflexible*. The hydraulic system of loading devised by Mr. Rendle, of Sir William Armstrong's firm, has, however, considerably modified the conditions, and the hydraulic checks by which recoil is reduced to a minimum, have so far contributed to economy of space, that it may now be found possible to work a gun of fifty feet in length within turrets only slightly larger than those of the *Inflexible*. If not, this length, and consequently the power and accuracy of the weapon, will have to be somewhat diminished, though it is thought that the 800 lb. powder-charge and the 4,000 lb. projectile might still be used. At all events, the factories at Woolwich are quite equal to any demands that might be made on them to build guns of either 164 tons or 200 tons, and the choice between these two now rests with the Admiralty authorities and their constructors.—*Iron.*

BOOK NOTICES.

REPORT ON THE JETTY SYSTEM AS APPLIED TO THE CHANNEL OF ENTRANCE TO CUMBERLAND SOUND. By Maj.-Gen. Q. A. GILLMORE. New York: D. Van Nostrand.

This is an important contribution to the discussion which so largely engages the attention of engineers, at the present time.

Gen. Gillmore's success as an engineer, and as a writer on engineering practice, will ensure a wide reading to this brief report. Like the author's previous performances in scientific essays and reports, the present one is free from any waste words, is equally free from theoretical mathematical investigation, with its double integrals, but is full of practical science.

Three folding plates illustrate the report.

REPORT ON THE TRANSPORTATION ROUTE ALONG THE WISCONSIN AND FOX RIVERS By Maj.-Gen GOUVERNEUR K. WARREN. Washington: Government Printing Office.

This report is a valuable addition to the literature bearing on the Hydraulics of our American Rivers. The survey of which this is the final report was made by direction of the government, with special reference to the improvement of water-transportation between the Mississippi River and Lake Michigan. To engineers the Report will be chiefly valuable as a scientific treatise on the improvement of shallow rivers of considerable slope, small volume, and movable bed.

The Report is divided into five chapters, of which the first three are chiefly historical, the fourth is descriptive of the rivers, their hydrology, and the adjacent territory as shown by the survey; the fifth is on "the methods of improving navigation," and is entitled to the most respectful attention of the engineering profession.

Ten folding plates illustrate the report.

A CONCISE HISTORY OF THE IRON MANUFACTURE OF THE AMERICAN COLONIES TO THE REVOLUTIONARY WAR, AND OF PENNSYLVANIA FROM THEN TO THE PRESENT TIME. By JOHN B. PEARSE, A. M. Philadelphia: Allen, Lane & Scott. For sale by D. Van Nostrand. Price $2 00

The above title sufficiently explains the scope of this work. No pains have been spared apparently to make this history complete.

It is a record of the changes in the iron trade, and of the successive improvements in the iron manufacture.

A large authentic map contains the geography of iron mines, and iron works of Pennsylvania.

THE INSURANCE CYCLOPEDIA. By CORNELIUS WALFORD, F. L. A., F. S. S. London: Charles & Edwin Layton. For sale by D. Van Nostrand. Price $9.00 per vol.

This work in six large royal octavo volumes, contains, first, a complete dictionary of the definitions of all terms, relating to insurance in all its branches; secondly, A Biographical Summary, of the lives of all contributed in any way to the development of the theory and practice of Insurance; thirdly, A Bibliographical Repertory, of all works on the subject of Insurance, and its associated sciences; fourthly, An Historical Treasury, of events connected with Insurance Companies; fifthly, A detailed account of the rise and progress of Insurance in Europe and America.

Three only of the six volumes, are as yet published.

PRACTICAL TUNNELING. By FREDERICK WALTER SIMMS, C. E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $12.00

This is a third edition of a well known and standard work, revised and extended by D. Kinnear Clark, C. E. In addition to the matter included in the former editions, the present volume includes an elaborate elucidation of the latest developments of tunneling practice.

The systems of driving tunnels known on the Continent, as the English and the Belgian systems, based on the bottom heading, and the top heading respectively, are fully explained. A discussion of the common casualties in tunneling occupies considerable space, as does also some details of experiences in tunneling in clay, marl, coal, and hard rock,

The St. Gothard Tunnel receives a full share of attention.

The whole work is executed in a style not excelled by any scientific volume in any country.

THE FLEETS OF THE WORLD. By Com. FOXHALL A. PARKER. New York: D. Van Nostrand.

Commodore Foxhall A. Parker, of the U. S. navy, whose contributions to what may be termed "Nautical" literature, in the past have been of exceeding use and value, both scientifically and practically, has written a volume entitled "The Fleets of the World—The Galley Period," which can hardly fail, gaining its deserts, to have a very wide circulation and extensive reading. Commodore Parker's other works, such as "Fleet Tactics under Steam," "Squadron Tactics under Steam," "The Howitzer Afloat," and "The Howitzer Ashore," have became standards in our naval instruction schools, and have the highest place as authorities in our navy. We have been permitted to examine most of the advance sheets of Com. Parker's latest work, and have no hesitation in pronouncing it one of the most interesting character historically, and as a continuous chronicle of sea-conflicts and marine operations in early days, it is marvelously entertaining as well as instructive. The volume deals with the "Galley Period" of China, of Egypt, of Phœnicia, of the Greeks and Persians, the Danes, and in short of all peoples, a portion of whose community engaged in sea-faring in the age which has now long passed away. The transcript shows the author to be a diligent scholar and student himself; one who has read and collated, gathering from great masses, the material which he needs for his work. The style of the writer is delightfully fresh and easy, his pictures of the ancient "marine service" being extraordinarily clear and comprehensive. Hardy's father, in "Tom Brown," might here find some of his doubts concerning the triremes, settled quite effectually. Com. Parker, first having received the statements of the past, is not always inclined to rely wholly upon them, but with critical acumen separates the probable from the improbable, his judgment so well founded by personal experience and careful study being certainly worthy of the highest respect. From a major part of the volume we can judge the whole, we think, and commend it in advance to the attention of our readers, as a most able production in a new field. In conclusion, we can only say, it is exceedingly pleasant to note the devotion of his leisure time to literary pursuits wholly beneficial to the community about him, of a gentleman whose skill in his profession is always acknowledged.—*Boston Traveler.*

KNIGHT'S AMERICAN MECHANICAL DICTIONARY: A Descriptive Word-book of Tools, Instruments, Machines, Chemical and Mechanical Processes etc., etc. By EDWARD H. KNIGHT, A. M, Civil and Mechanical Engineer. Boston: H. O. Houghton and Company. For sale by D. Van Nostrand. Price $8.00 per vol. in cloth.

The third volume of this excellent work is just issued. It will prove indispensable to all whose interest involves a knowledge of mechanical appliances, or even of a history of their origin and use, for the work is a history of inventions as well as an Encyclopedia.

The Author has invented a system of what he terms "SPECIFIC INDEXES," by the use of which the inquirer is guided straight to the information he is in quest of, even though he be entirely ignorant of the name of a thing, and have but the most vague and general notion of its use. This is accomplished by grouping under the general title of each science, art, trade, or profession, a list, or "specific index," of every article in the book bearing any relation to the subject in question. The titles of these Indexes are in turn grouped on page v., Vol. 1, so that by a glance one may determine which clew to follow.

This work is the result of twenty-five years' application, much of the time having been passed by the Author in the United States Patent Office, where he was engaged in editing the Patent Office Report, and classifying patents; and subsequently editing the "Official Gazette," and systematizing for examination the 20,000 applications for patents which yearly are presented to the office. Sitting at the very center and focus of the mechanical thought of the country, he saw the necessity for a compendious Description of the Tools, Machines, Processes, and Appliances of the Arts and Sciences,—in short, a *Dictionary of Mechanical Terms.*

The work treats of 20,000 subjects, and is illustrated with 7,500 carefully prepared engravings. It would indeed be correct to say that the illustrations are fully 15,000 in number, in as much as a variety of distinct forms of a machine or tool (sometimes as many as forty) are frequently associated in a single cut, and might, had the object been to spread them out and make a show, have been enumerated as separate figures.

After eight years of active preparation, the work has just been completed, and may be had, *by subscription only*, in forty-four parts of sixty four pages each, or in three bound volumes.

FORMULAE FOR THE CALCULATION OF EARTHWORK. By JOHN WOODBRIDGE DAVIS C. E. New York: J. Dickson & Bro. Printers.

The author presents as new the following topics, viz:. First, the inclusion of volumes of minor length in the general series, whereby the inequality in length of consecutive volumes forms no interruption to a single and speedy operation. Next, the attainment of a single formula for all varieties of irregular and defective volumes, which not only abbreviates the computation of each, but allows them all to be included in the same series with ordinary volumes, so that any entire cut or bank can be estimated accurately in one operation. Approximate formulæ, on account of their simplicity, are used in the combinations, and the results corrected by an exceedingly easy formula, thus obtaining the contents as by the prismoidal rule.

Although the original idea of the author was to secure the maximum amount of brevity, by combining everything without exception in series, and then eliminating every constant factor and term from the calculation of each, inventing for this purpose, several devices not

hitherto used, yet he has not allowed himself to be tempted away from exact work, deeming this to be of the first importance.

The claim for the method is *absolute accuracy*, joined with what brevity is shown to arise from the use of the resulting formulæ.

The work is used as a text book in the School of Mines, Columbia College.

QUALITATIVE CHEMICAL ANALYSIS: A Guide in the Practical Study of Chemistry and in the Work of Analysis. By Prof. SILAS H. DOUGLAS and Prof. ALBERT B. PRESCOTT. Second Edition Revised. New York: D. Van Nostrand. Price $3.50

This enlarged edition of an excellent work has grown out of Douglas' Tables for Qualitative Analysis, first published about twelve years since. These tables soon became widely known to students, so that a second and a third edition quickly followed.

The first edition of the present work, representing the joint labors of the two writers, appeared three years ago. The present edition, just out of the press, embodies much additional matter, and is carefully made to accord with the recent confirmed discoveries in practical chemistry. It is especially designed for a text book for students, while each section has been expanded beyond the immediate requirements of the beginner, to the extent of serving the purposes of the practised analyst. Two kinds of type serve to point out the division between the section and its supplementary portion.

Some differences between this work and the ordinary works on Analysis, are observed in the treatment of the "Iron Group." The procedure is made to depend upon the presence or absence of Phosphates, so that when the process of search has reached this third group, the evidence of phosphoric acid is sought for. If absent, Ammonium Chloride and Ammonium Hydrate, are added to separate the pseudo-triads. Iron Chromium and Aluminum as a sub-group; then the remainder of the third group are precipitated in the old way.

This is not given to the exclusion of the former method, only as a valuable addition to it.

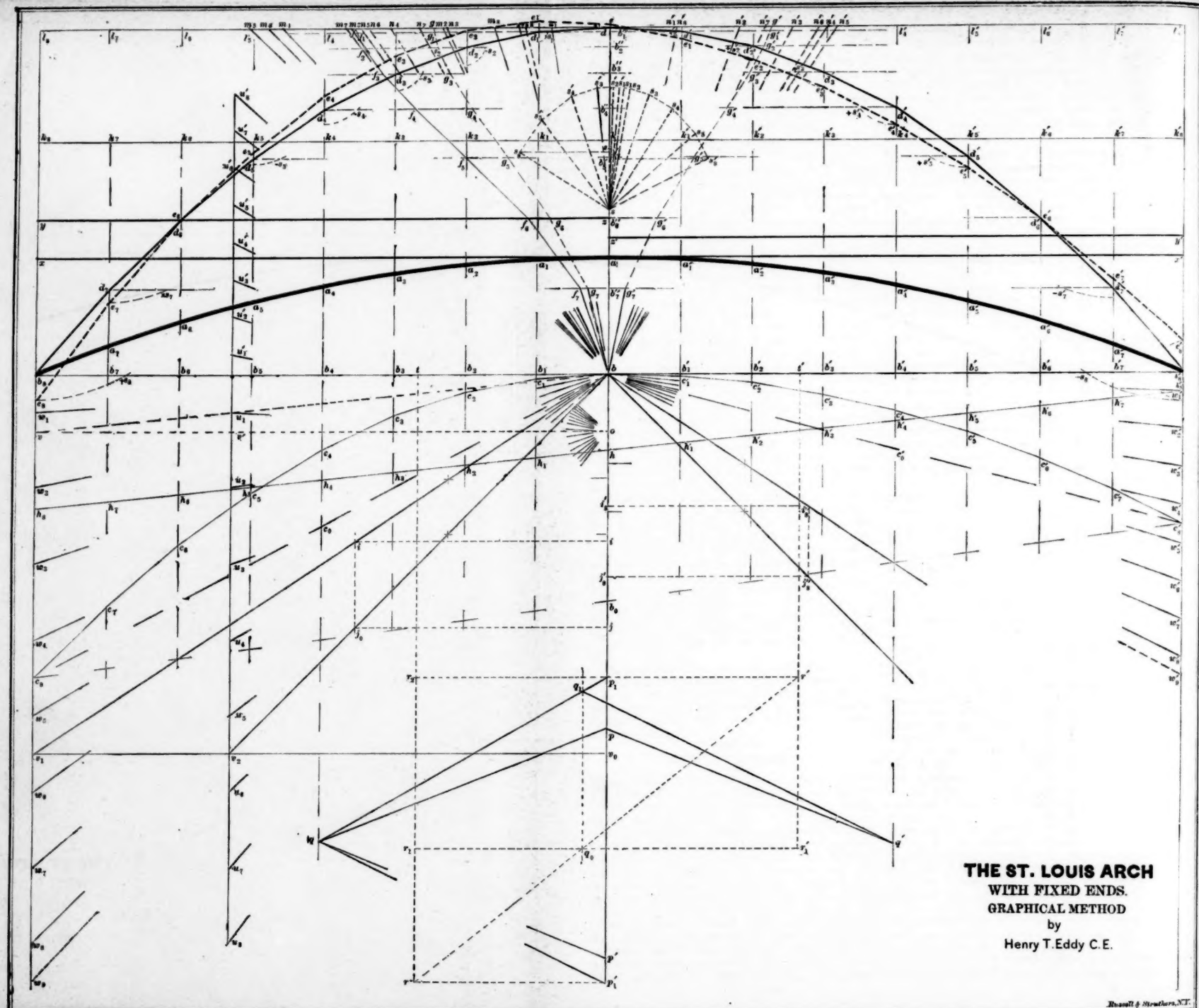
Some new reactions of the rarer metals are given, and a valuable table of solubilities of metallic salts. The new notation is used throughout.

MISCELLANEOUS.

FURNACE LINING.—M. E. P. Audouin of Paris, France, has invented a composition which he says is calculated to more effectually resist the action of oxide of iron than any other material heretofore employed for the purpose. This material is oxide of chromium, which is capable of resisting the very highest temperatures employed in furnaces and laboratories—such as the Siemens furnace, and furnaces heated by dead oils—and is also proof against the action of oxide of iron at the highest degrees of heat. The inventor claims that there is no danger of the oxide being reduced under the ordinary conditions of working; and, moreover, the presence of a small quantity of chromium will not affect the quality of the iron. This oxide may also be utilized in the manufacture of fireproof blocks to be exposed to the action of furnace cinder and scoria, but with less advantage, as by the action of certain principles, more especially potash, soda, and lime, chromates are eventually found.

THE NEW TARGET AT SHOEBURYNESS.—The iron target for testing the powers of the 38-ton gun is now ready in the marshes at Shoeburyness. It consists of three plates of rolled iron, ten feet by eight feet, each 6½ inches thick, and weighing nine tons. Between the plates are layers of teak five inches in thickness, and they are all bolted together by sixteen 3-inch bolts, eight others attaching the structure to the timber strutting in rear. The strutting consists of three piles, fourteen inches in diameter and fifteen feet long, and of three shorter piles seven feet behind, but connected by braces framed and bolted. The row of short piles butts up against an old iron target, also strutted with timber. To increase the stability of the target, its sides are strutted by means of old 6-inch plates held in position by the rods passing in front and rear, and these are also braced. The top of the target is covered with an old 8-inch plate, and is secured by railway bars bolted underneath the plate, and through the old target at the back. The trial will consist of only one round, and although 19½ inches of iron (without reckoning the wood) is more than the gun has yet attempted to penetrate, it is believed that it will accomplish the task.

USE OF SULPHATE OF ALUMINA FOR THE PRECIPITATION OF SEWAGE.—The question of the utilization of sewage has again come before the French Academy of Science, this time in connection with the discovery of a large bed of kaolin in the department of Mayenne. It is well known that sulphate of alumina has often been proposed as an agent for precipitating the organic matter contained in sewage, and that experiments on a large scale have been made. M. Cagnant, the discoverer of the bed of china-clay, is of opinion that the possibility of manufacturing this salt at a much lower price than heretofore will permit of extending the experiments, and of arriving at more satisfactory results than have hitherto been obtained. M. Belgrand, however, observed that the high price of the re-agent was not the only reason why its use as a precipitant had been rejected. The construction of basins sufficiently large for the treatment of the enormous quantity of water used daily by the capital would lead to an expense out of all proportion to the value of the products that must be obtained; the removal of the deposits formed in the basins would involve a considerable amount of labor; and this practice would be as deleterious to health as leaving the sewage in the river. M. Belgrand was convinced that, regard being had to the volume of water to be got rid of, the best method after all, was to utilize the sewage itself, as a vehicle for the fertilizing matters it may contain, and that irrigation is the only method really practicable, provided, however, that it be practised over a sufficiently large area.



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